M.O. 514 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 78. No. 919. JANUARY 1949

DR. C. E. P. BROOKS, I.S.O.

It is granted to few of us to devote over 40 years of our careers to the study of a particular branch of meteorology. Dr. Brooks was, however, given this opportunity, and everybody knows the excellent use that he has made of it.

Brooks entered the Meteorological Office as a Probationer on October 4, 1907. The following month he was posted to the Library Branch of the Statistical Division. The Statistical Division of that time was the forerunner of what we now call the Climatology Division, and it is with the Library and Climatology Division that Brooks has remained uninterruptedly associated until his retirement this month.

Five years after joining the Meteorological Office, Brooks graduated as an external student of London University with Honours in Geology. This was followed by the M.Sc. in 1916 and the D.Sc. in 1926. The acquisition of these academic honours affords a striking illustration of what can be achieved by ability and hard work.

Brooks has published a very large number of papers on climatology. His studies have not been confined to the climate of the British Isles, but have embraced the whole world. He has, for example, made a special study of the world distribution of thunderstorms. Another field in which he has left his mark is in the study of changes of climate over the world in geological time. Brooks was always an omnivorous reader, and he possessed to a remarkable degree the ability to remember a vast amount of what he read. His reputation as a climatologist is world-wide, and his advice has been sought by meteorologists in many countries. His name will always be associated with the production of the first 25 years of the *Réseau Mondial*, that great conception of Sir Napier Shaw's which fell to Dr. Brooks to implement.

Mention was made earlier of Brooks' association with the Meteorological Office Library. The Meteorological Office owes a great debt to Dr. Brooks for having built up the present excellent Library. When he joined it, the Library was a relatively small affair; Brooks has grown up with it, leaving his mark firmly impressed upon it. Working in close association with the Librarian of the Royal Meteorological Society, Brooks has made it possible for meteorologists in this country to have access to almost every meteorological paper they are likely to call for. He has also been primarily responsible for the introduction into British meteorology of the Universal Decimal Classification System of Notation.

Brooks' fluent literary style made him the obvious choice for Editor of the *Meteorological Magazine*, a post which he has filled with distinction for 22 years. The zeal with which he performed this task is illustrated by the fact that, although the *Meteorological Magazine* could not be printed during the war, a typescript edition was prepared at Stonehouse and circulated among Headquarters.

From his early days, Brooks has shown a great interest in statistical climatology, and he has been largely responsible for the recent developments which have taken place in this field. He is at the moment engaged in writing an official manual on the subject, which promises to become of increasing importance.

Brooks has represented the Meteorological Office at many international meetings, and last year was the Meteorological Office member on the I.M.O. Commissions for Climatology and Bibliography and Publications at Toronto.

The contribution which Dr. Brooks has made to the work of the Meteorological Office was recognised by his creation as a Companion of the Imperial Service Order in June of this year. Rarely can this distinction have been so richly deserved.

On the human side we shall think of Brooks as a colleague who was always anxious to help and who never spared himself in the common cause. His sincerity and good humour gained him the friendship of all who had dealings with him.

Dr. Brooks retired on November 10 from his permanent appointment in the Meteorological Office, but I am glad to say that he has agreed to accept a part-time appointment which will enable him to continue to help us. Although he is not leaving us for good, it has been thought that the present occasion is a suitable opportunity for expressing our appreciation of all that he has done for us, and for wishing him many years of health and happiness yet to come.

Presentation to Dr. C. E. P. Brooks

The presentation of a comptometer and a clock to Dr. Brooks on his retirement was made by the Director on behalf of the staff of the Office before the Discussion on November 29.

Expressing the good wishes of the staff to Dr. Brooks the Director gave the appreciation of Dr. Brooks' career which is printed above.

Dr. Brooks, thanking the staff for the gift, said that perhaps in future they would think of him as racing the comptometer against the clock. With the first money he had earned with his pen forty years ago he had bought as a memento a clock which strangely broke down almost on the day of his semi-retirement. This new one would be a permanent memento of the kindness of the Office. As for the comptometer he always had some correlation coefficients to work out or other calculations on hand. Referring to his career he mentioned that he had originally intended to be a geologist and had become a meteorologist rather by accident. He did not regret this as geology was rather a lonely profession and he had never been lonely in the Meteorological Office, the staff of which were always so friendly. He had thoroughly enjoyed his forty-one years full-time work in the Office but was enjoying his semi-retirement even more.

TWEED VALLEY FLOODS

Heavy rainfall of August 11–12, 1948

By J. GLASSPOOLE, Ph.D.

The unprecedented floods in the border country, resulting from the heavy rains of August 11–12, caused widespread damage, estimated as likely to exceed £1,000,000 in value in Berwickshire alone. The map on p. 4 shows the distribution of the rainfall for August 12. The largest values for the 12th occurred along the main valley of the River Tweed, where a large area received more than 5 in., but there was also rather more than 5 in. over part of the Lammermuir Hills, at the headwaters of the Whiteadder, which flows into the Tweed a few miles above Berwick-on-Tweed. The daily amounts for the 12th at the four stations in the Tweed Valley, as set out below, correspond to from 20–23 per cent. of the average annual rainfall, and at Kingside in Lammermuir to 16 per cent. So large a proportion of the average annual amount rarely falls on one day in this country. The proportion was greater, being from 25–30 per cent., near Norwich on August 26, 1912, at Doncaster on September 17, 1913, at Bruton on June 28, 1917, and at Cannington on August 18, 1924.

The proportion was also probably exceeded by the rains which caused the Moray floods of August 1829 but no records are available for the area of heaviest rain.

The amounts for August 12, 1948, are the largest on record for this area, the previous largest for one day for Berwickshire being 3·30 in. on June 24, 1911.

Rainfall, August 6–12.—The daily values for the seven days August 6–12 are set out below for four stations situated from Kelso down the main valley to Tweedhill, as well as for Kingside in Lammermuir.

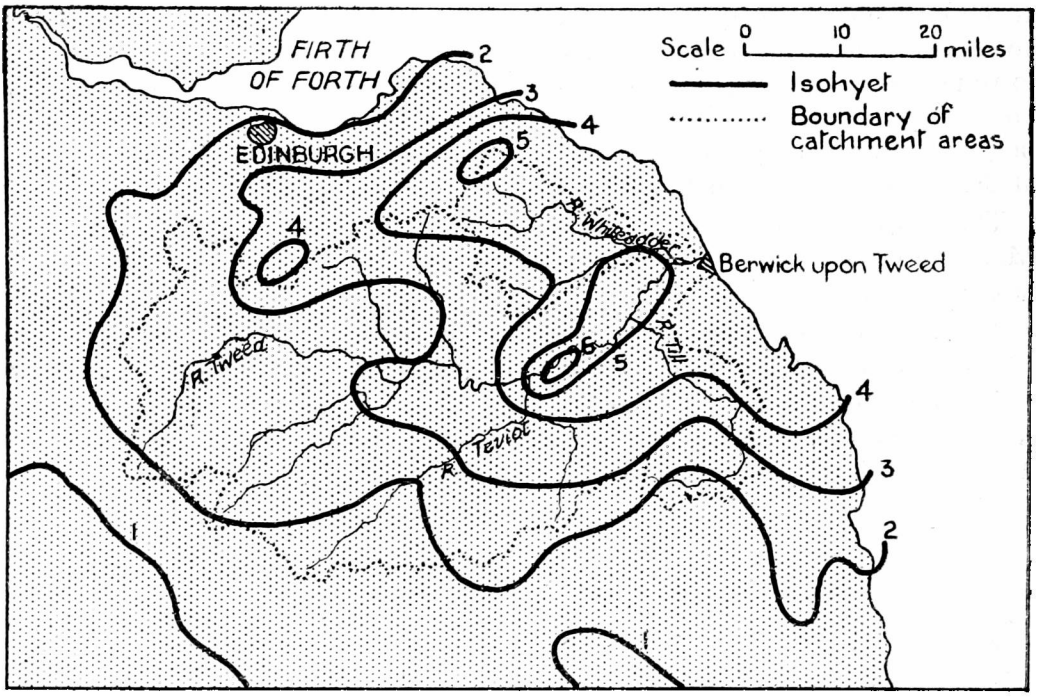
	Daily rainfall in early August							Total
	6th	7th	8th	9th	10th	11th	12th	
	inches							
Kelso (Floors Castle) ..	0·16	1·09	0·20	0·15	0·02	0·54	6·21	8·37
Hendersyde Park	0·18	1·10	0·19	0·10	0·01	0·70	5·42	7·70
Swinton House	0·23	1·37	0·26	0·11	0·08	0·88	5·10	8·03
Tweedhill (Hutton Parish)	0·32	1·93	0·42	0·22	0·00	0·73	5·55	9·17
Kingside in Lammermuir	0·50	2·64	1·44	0·04	0·05	0·47	5·48	10·62

A measurement for the 12th was also made, using a standard gauge, at Carham Hall, Cornhill-on-Tweed, Northumberland, some 7 miles east of Floors Castle, of 6·25 in., but the daily amounts for the other days are not available. The totals for August 6–12 correspond to from 30–35 per cent. of the average annual rainfall amounts at these stations, and so large a proportion of the annual average in 7 days is a rare occurrence anywhere in this country.

Duration and intensity of the heavy rain.—The incidence of the rainfall of the Upper Till, draining to the Tweed below Coldstream, is probably represented by the record at Howick Hall, to the east of Alnwick, where the amounts for the 11th and 12th were 1·21 and 3·22 in. Of this total of 4·43 in. as much as 4·34 in. fell in 24 hours from 10 p.m. on the 11th to 10 p.m. on the 12th. The heaviest rain occurred there between 9 a.m. and 2 p.m., when in 5 hours 2·59 in. was recorded at a rate of about ½ in. per hour. At Swinton House, towards Duns on the other side of the River Tweed, where the amounts for the 11th and 12th were 0·88 and 5·10 in., the heaviest rain was later, 1·90 in. falling in 2 hours after 4.40 p.m. and the total of 5·10 in. being confined mainly to 15 hours from 9 a.m. to midnight.

Area covered by the heavy rain.—For August 12, 1948, the areas, in square miles, covered by falls exceeding specified amounts (not restricted to the Tweed Valley) are set out below compared with the corresponding values for the Bruton storm of June 28, 1917, and Norwich rainfall of August 26, 1912*

	Tweed	Bruton	Norwich
		square miles	
more than 6 in.	8	85	268
more than 5 in.	130	288	720
more than 4 in.	800	809	1,071
more than 3 in.	1,525	1,931	2,007
more than 2 in.	2,900	4,419	3,827



RAINFALL MAP OF AUGUST 12, 1948 (Isohyets are in inches)

So far as the area with more than 4 in. is concerned the recent Tweed-Valley rains are therefore comparable with those of Bruton and Norwich. In the case of the Bruton storm it is considered that this rain fell in 16 hours, while in the Norwich floods, as much as 550 sq. miles received more than 6 in. and 1,660 sq. miles more than 4 in., in 20 hours on August 26–27, 1912.

Volume of rain-water in the Tweed Valley.—The general rainfall of this period is set out below both for (*a*) the whole of the Tweed Valley and (*b*) for the Tweed Valley excluding the Whiteadder, which enters the Tweed a few miles above the estuary.

	(*a*)	(*b*)
	in.	in.
August 11	0·6	0·5
August 12	3·2	3·1
August 6–12 (7 days)	5·4	5·1

*GLASSPOOLE, J.; The areas covered by intense and widespread falls of rain. *Proc. Inst. Civil Engrs., London*, **229**, 1930, p. 137.

Adopting the areas for the Tweed and Tweed less Whiteadder, used in *British Rainfall*, of 1,904 and 1,705 sq. miles respectively, the general rainfall values for August 12 correspond to volumes of (*a*) almost 400 million tons, and (*b*) almost 340 million tons (the difference 60 million tons representing the amount falling on the Whiteadder area).

Flooding in the Tweed Valley.—Following the heavy rain in the Tweed Valley on the 7th the Press on the 9th reported that the local swimming-club races had to be cancelled at Berwick-on-Tweed owing to the river being in spate. The 10th and 11th were poor drying days so that the ground remained saturated. From the early hours of the 12th there was continuous rain, by 3 p.m. the hillside streams had become minor torrents and by 6 p.m. the Tweed tributaries had overflowed their banks in the upper reaches. The worst flooding in the lower Tweed is reported to have taken place between 10 p.m. on the 12th and 11 a.m. on the 13th, with the maximum flood about 3 a.m. on the 13th. The peak is reported to have reached the mouth of the Tweed between 3 a.m. and 6 a.m. on the 13th, roughly 12 hours after floods had occurred in the upper reaches.

Synoptic situation

BY C. K. M. DOUGLAS, B.A.

The synoptic situation associated with the abnormal rainfall of August 12 is shown on the accompanying charts. At 0600 there was a shallow depression

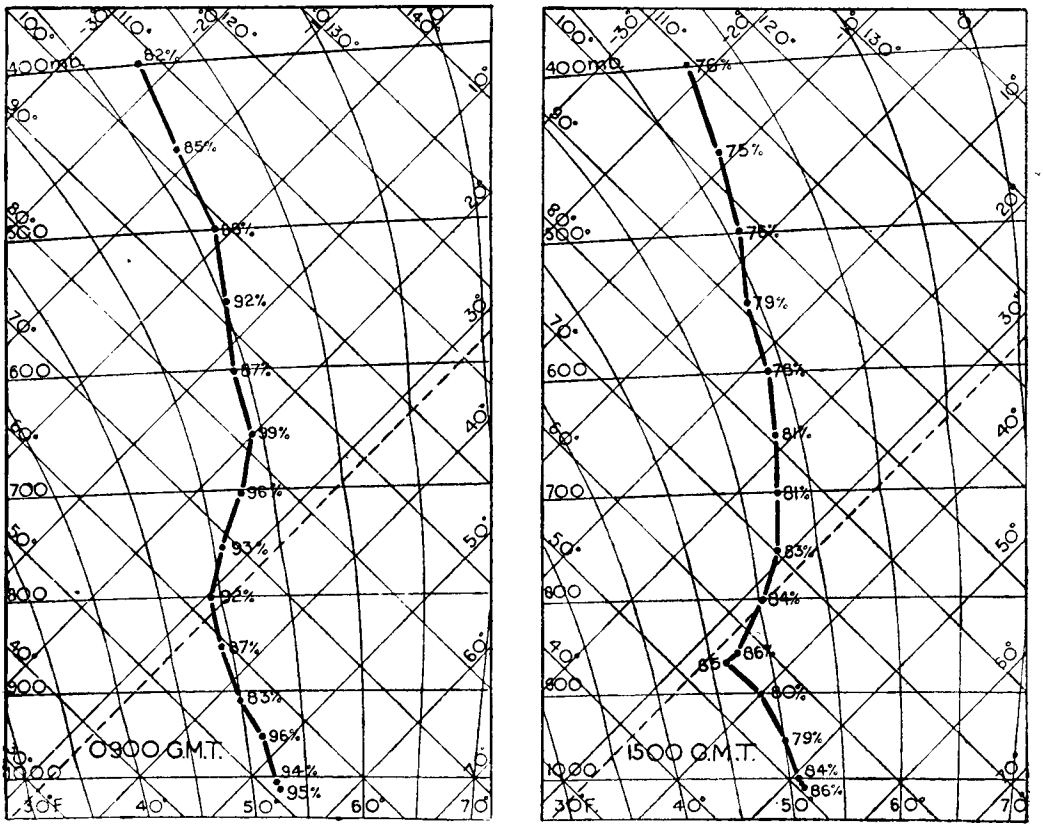


FIG. 1—TEPHIGRAMS FOR LEUCHARS ON AUGUST 12
Relative humidities are included

centred off the Norfolk coast. Its previous track is shown by the broken line joining the crosses which marks its position at successive 6-hourly intervals. It had moved east-south-east to a position off Valentia, then east, and finally east-north-east across Wales and England. Its comparatively slow motion had allowed its occlusion to become spiralled, and in addition the marked development of the upper trough behind it, due to the extraneous influence described below, produced a movement of the occlusion and a bulging of the depression towards north-east England and Scotland. The part of the spiralled occlusion nearest to the centre was no longer traceable, since there was no discontinuity at sea level and the rainfall had become patchy and mainly slight in that area. That part of the occlusion affecting our northern districts was of

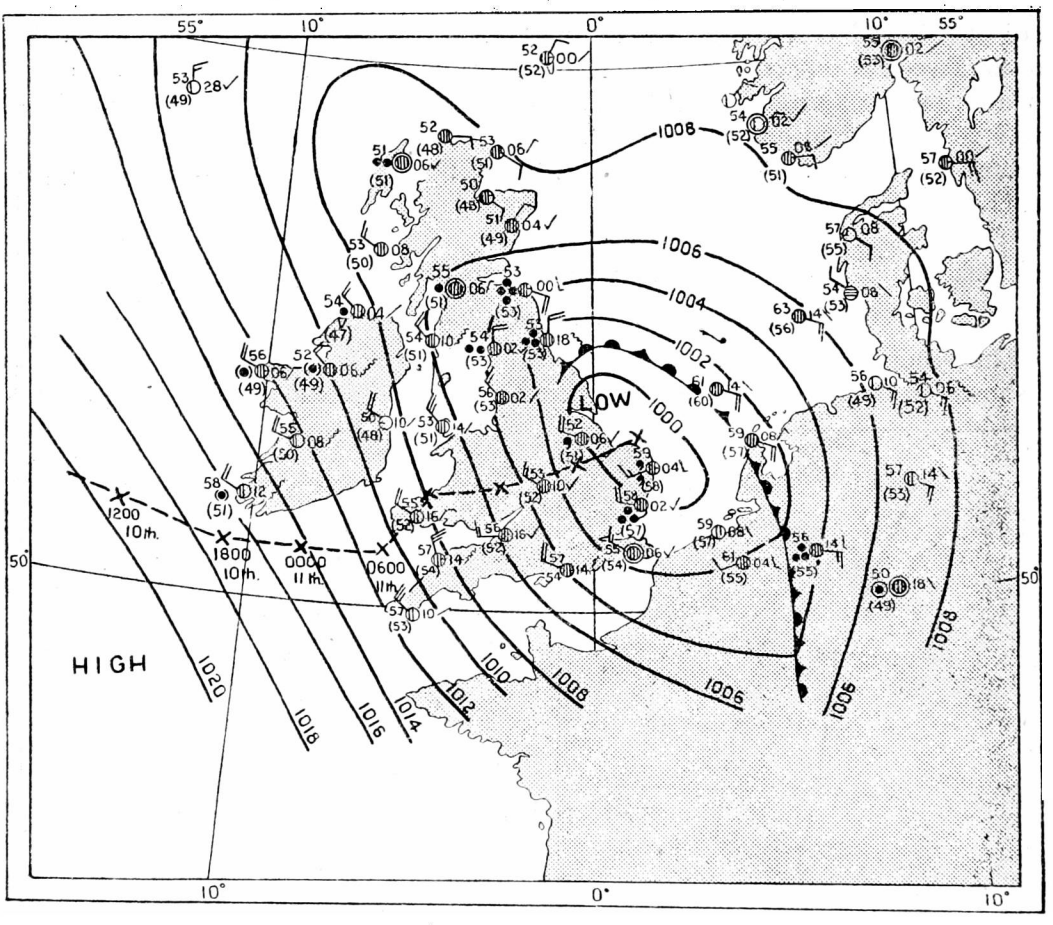


FIG. 2—SEA-LEVEL SYNOPTIC CHART, 0600 G.M.T. AUGUST 12, 1948
The chart shows temperature, dew points (in brackets), weather and barometric tendency; the track of the depression is included

warm-front type, whereas on the continent it was of cold-front type. Most summer occlusions on the continent are of cold-front type, but in the open sea at all seasons there is a natural tendency for the characteristics of a curved occlusion to vary along its length. In this case the depression had been occluded since August 9 and the air, which had ascended from its warm sector, had passed well to southward of the British Isles. The maritime-polar air behind the occlusion had crossed a warm sea area to the south of Ireland and had then gained heat and moisture over England. The water-vapour content of the column of air was not outstandingly high for the time of year, and had

been exceeded on a number of occasions in the preceding fortnight. The air over northern districts ahead of the occlusion had originally formed part of a cold northerly air stream over the Norwegian Sea on the 10th.

Late on the 11th thunderstorms with heavy rainfall developed in the Midlands, behind the occlusion, close to the centre of the depression. These must have contributed to the building up of a thick cloud system extending to the tropopause (about 34,000 ft.) and since the air in which the thunderstorms formed afterwards ascended at the front, this development must have added to the intensity of the rainfall. The tephigrams for Leuchars on the 12th (Fig. 1) showed that frontal action had produced a thick stable layer, and that the rainfall was by then of purely frontal and not of instability type. Leuchars

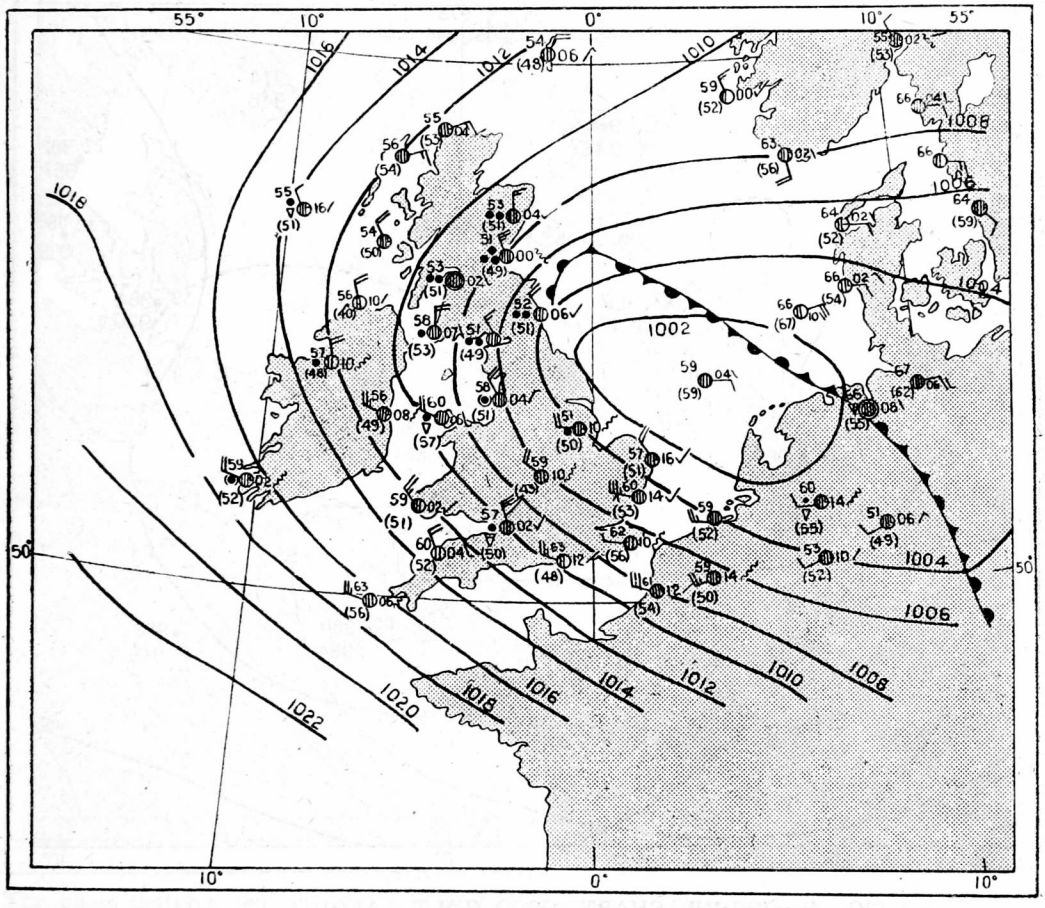


FIG. 3—SEA-LEVEL SYNOPTIC CHART, 1800 G.M.T., 1948

had 32 mm. of rain between 0900 and 2100 on the 12th. This station is about 55 miles north-north-west of the region of maximum rainfall round Kelso.

By 0600 on the 12th (Fig. 2) the area of heavy rainfall had moved northwards to Northumberland and Berwickshire. By 1800 (Fig. 3) it had moved a little to north-west and had begun to weaken, and turn west to south-west. There was further considerable rainfall in south-west Scotland during the night. One can deduce from the tephigrams that the occlusion advanced slightly, but it never reached the coast at sea level and there were no observations to show its exact position.

Figs. 4 and 5 show contours of the height of the 700-mb. surface (continuous lines) and of the 1000–700-mb. thickness (broken lines). The absolute heights are plotted above the thicknesses. The wind direction at 700 mb. is shown by the continuous arrows, and the velocity in knots by the figures in the circles. The broken arrows and the figures at their tails are the vector differences between winds at 950 and 700 mb., closely related to the thermal winds. Temperatures at 700 mb. are also plotted.

The thickness lines indicate the distribution of mean temperature in the 1000–700-mb. layer. There was a warm tongue over and east of the occlusion and a large cold tongue on the south-west side of the depression, and probably a small cold pool near north-west Ireland. This cold air had moved south-east

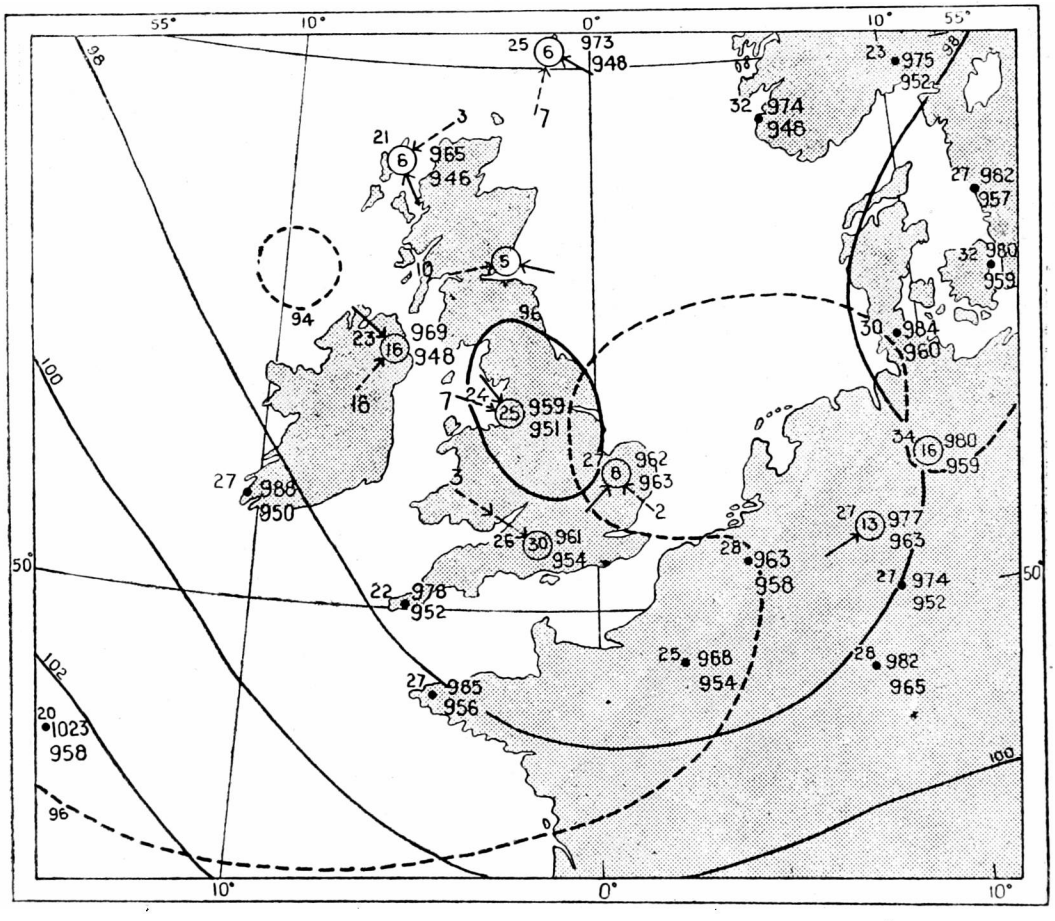


FIG. 4—700-MB. CHART, 0300 G.M.T., AUGUST 12, 1948
The chart shows contours (full lines) and thicknesses (broken lines) at intervals of 200 ft. (For further explanation see above)

from west of Iceland for reasons initially independent of the depression which crossed England. It belonged to a cold depression which moved south-west from Iceland and filled up off the Hebrides, where there was a bulge in the isobars at 0600 on the 12th (Fig. 2). A cold front at the south-east boundary of this current crossed our south-west districts and France, but there was no front separating it from the equally cold air mass to the north of the depression, part of which came round the rear of the depression at low levels. The new cold outbreak gave rise to over-running cold air at the centre of the depression and

thus to instability. It also led to the backing of the upper wind, which carried the rain into Scotland. There was no easterly wind component at 700 mb. observed anywhere up to 2100 on the 11th, and even at 0300 on the 12th (Fig. 5) the east component was still very weak. The upper wind advected the moisture and indirectly added to the intensity of the rainfall, through its effect on the field of acceleration. A trough extended north-west from the centre of the depression, the gradient for NE. wind steepened over Scotland, and the cold air was accelerated to the south-west, with a resulting ageostrophic movement towards south-east. The Leuchars winds, tabulated below, show an increase of velocity low down between 0900 and 1500, and at 1500 the wind at 900 mb. was backed some 20–25° from the sea-level isobars. This involved an ageostrophic wind

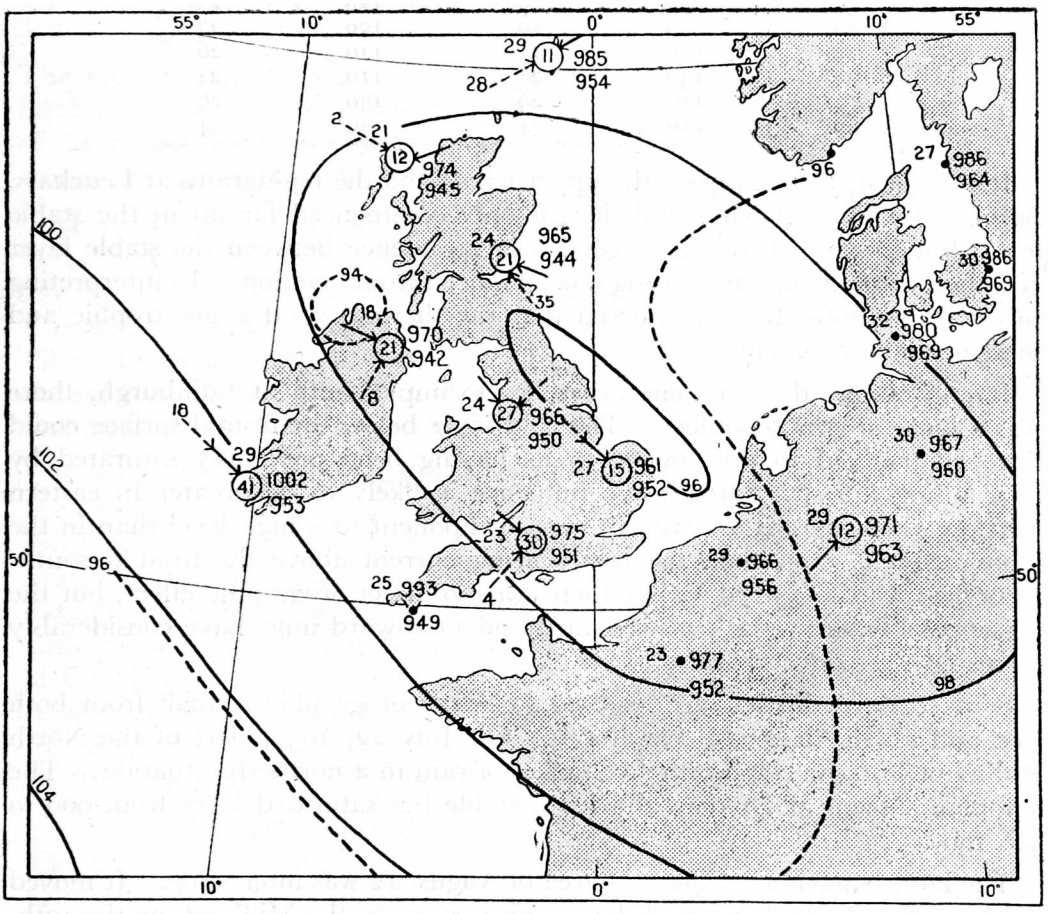


FIG. 5—700-MB. CHART, 1500 G.M.T., AUGUST 12, 1948
The chart shows contours (full lines) and thicknesses (broken lines) at intervals of 200 ft.
(For further explanation see p. 8)

of 10 or 12 kt., and the associated convergence at the front would be adequate to give the 32 mm. of rain observed at Leuchars in 12 hours. The heaviest rainfall was further south, where there was undoubtedly marked convergence, but there were no upper wind observations close to the region of maximum rainfall.

The south-east movement of the dying low from Iceland helped to produce a trough of low pressure orientated from north-west to south-east and this affected the location of the heavy rainfall and probably added to its amount by increasing the convergence. Nevertheless the front and the associated

slight fall of pressure spreading north and then north-west from the main depression was probably the most important cause of convergence.

The upper winds over Leuchars were as follows:—

Pressure	0900 G.M.T.		1500 G.M.T.	
	Direction	Velocity	Direction	Velocity
mb.	°	kt.	°	kt.
950	050	16	020	23
900	060	17	020	27
850	060	17	030	25
800	030	16	060	21
750	350	18	090	18
700	010	15	110	21
650	050	9	120	23
600	050	10	120	27
550	120	14	110	26
500	130	24	110	24
450	150	29	130	28
400	140	34	140	34

It is interesting to compare the upper winds and the tephigrams at Leuchars. At 0900 the veer of wind with height only commenced far up in the stable layer, but at 1500 there was a good correspondence between the stable layer and the region of veer, indicating a pronounced frontal action. In interpreting this action it must be remembered that the thermal wind is geostrophic and therefore non-divergent.

It is probable that in some areas, for example south of Edinburgh, there was a large orographic effect. The cold layer below the frontal surface could have contributed to this, owing to its having been previously saturated by rain falling into it. Orographic influence is likely to be greater in eastern districts when there is an easterly wind component to a high level than in the more frequent case when the rain-bearing current above the front is south-westerly. In the Tweed Valley there was no direct orographic effect, but the presence of extensive hills to westward and southward must have considerably increased the convergence.

Some eastern districts are exposed to heavy orographic rainfall from both east and north, in special conditions. On July 22, 1930, part of the North Riding of Yorkshire had over five inches of rain in a northerly situation. The aeroplane ascent at Duxford showed a stable but saturated layer from 900 to 500 mb.

The later behaviour of the rain area of August 12 was interesting. It moved south-west to the Irish Sea and then south-east across the Midlands on the 13th, thus making a complete circuit round the slowly moving 700-mb. centre. Rainfall amounts were small on the 13th, but 0·12 in. fell at Croydon and Felixstowe. The upper wind backed in Scotland and weather was fine and sunny on the 13th. The last appearance of the depression as a separate centre was off Helder at 1800 on the 13th. It degenerated to a trough in the circulation of a new system over Poland and moved south.

To sum up, the phenomenal rainfall was due to an exceptional combination of factors and cannot be adequately explained even after the event. The probability of recurrence of this particular combination of circumstances is clearly very small. Excessive rainfall could be produced by developments different in detail, but as is mentioned in Dr. Glasspoole's note, the largest

fall previously recorded in that area was very much less, and the chances of six inches of rain in a day in any area are always exceedingly small. The Norwich rainstorm accompanied a depression which deepened to 978 mb. close to the region of maximum rainfall, and which produced gales near its centre. The Bruton rainstorm was related to a shallow depression moving slowly east in the English Channel. The Tweed rainstorm differed from either of these in that the main cyclonic centre was 250 miles off and developed a temporary protrusion towards the north-west.

CHINESE "RAININESS" THROUGH THE CENTURIES

By D. JUSTIN SCHOVE, B.Sc.

The meteorological annals of China are far more detailed and extend much further back in time than those available in European chronicles. The dating of the events has been checked with reference to the known dates of Halley's comet since at least 87 B.C. and of eclipses since 720 B.C.

Most of the meteorological events from 206 B.C. to A.D. 1634 were listed in the T'u-shu Chi-ch'eng (Section IV: "Strange phenomena" chuan 86–92, 124–130), which is available in the British Museum and in the Bodleian Library. This was completed in 1726 and may indirectly have inspired Dr. T. Short and Pilgram to make, later in the century, similar but less accurate lists for Europe. Subsequent Chinese events have been included in the "Treatise on calamities and anomalies", Chapters 40 and 43 of the Ch'ing Shih Kao.

Extracts from the "Strange phenomena" in the great encyclopædia have been made and incomplete lists of floods, droughts, comets, auroræ, sunspots, shooting stars and eclipses in China have been published in England and France during the past two centuries. Statistical interpretation of the data has, however, been begun only recently and that has been initiated by the Chinese themselves. The pioneer in this field is Dr. Coching Chu (President of Chekiang University) who, on the basis of the recorded number of floods R and droughts D calculated[1,2*] a raininess factor D/R for each century (cf. Brooks[3]). Yao[4,5,6] has now extended this investigation, and has used the two above-mentioned sources to obtain more detailed information.

In Fig. 1 curves have been drawn to illustrate the various indices of raininess. The data of Yao and Chu are represented by curves (1) and (2) respectively. Curve (3) is based on an earlier selection of data by Hosie[7,8] which is very inadequate as far as floods are concerned, but is included to indicate half-century tendencies.

The agreement between the curves (1) and (2) is striking but deceptive. Both curves also agree, at least to A.D. 600, with curve (4); this curve is not an index of "raininess" at all but rather an indication of the total amount of regional information available since it represents the total of all floods and droughts in Yao's regional tabulations (Table XI). It is evident that when local records are least complete, as in the fourth and sixth centuries, floods rather than droughts tend to be omitted. In Europe a similar tendency can be observed.

*These numbers refer to the list of references on p. 15.

The belief in progressive dessication has not been supported by recent investigations either in Africa or China, except inasmuch as it is a consequence of local deforestation. On the other hand the apparent trend towards increased wetness in curves (1) and (2) is equally illusory, and, pending the results of pollen-analysis, must be regarded merely as a reflection of the growth of detailed records. It is for instance particularly noticeable about the second and tenth centuries—centuries associated with the invention and the wide diffusion of paper and printing respectively in China.

An attempt has been made in Table I to correct for the variability of record by a simple formula. A more refined method of correction, such as used by Brooks and Glasspoole for Europe[9], may be possible when fuller data are available.

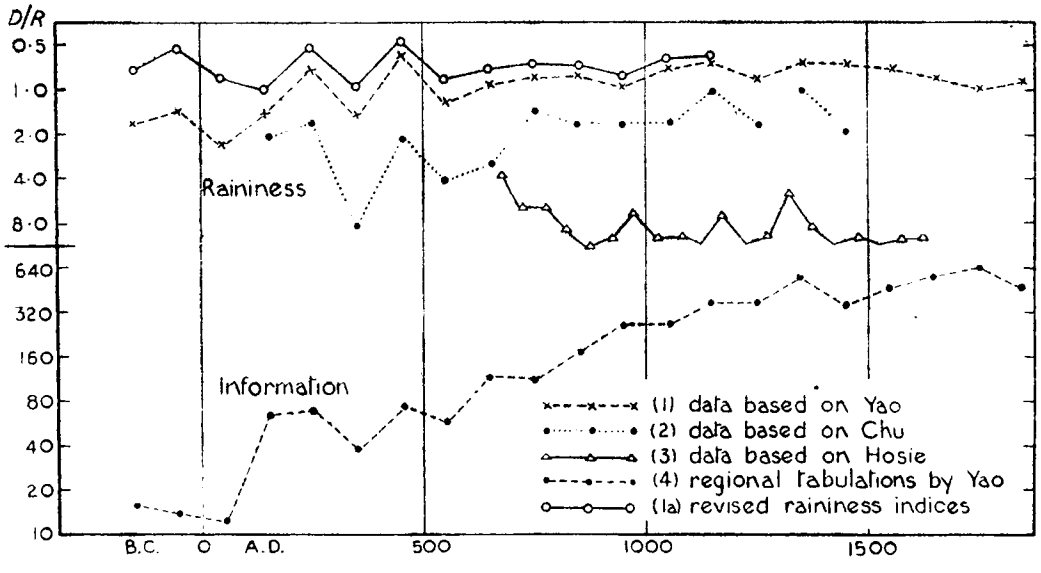


FIG. 1

The revised " raininess indices " (defined in Table I) are shown in the top curve (1a), but I do not regard even this as satisfactory evidence of climatic variations. The variations reflect rather the changes of capitals, canals and rivers. Analysis of eclipses in the same encyclopædia indicates that the regions of observation vary, e.g. from 32°N. 119°E. in the fourth century to 40°N. 116½°E. in the fifteenth, i.e. regions as far apart as Venice and Antwerp. As Yao stresses, the information is most complete from whichever areas were economically important at the time and, from the seventh century, when the east coast became densely populated, the information is more complete for this region than for that of " China's sorrow ", the Yellow River.

The flood and drought data were next classified according to Mallory's three regions—north, central and south China, which partly disposes of the above objections. The corresponding regional raininess indices are plotted in curves (5) to (7) (Fig. 2). Once again the trends are deceptive, but this time the trends appear to be towards increased dessication—merely because in early centuries the location of droughts was often unspecified.

The test of consistency suggests that the third, eighth and eleventh centuries are wet and that the fourth and twelfth are dry. Nevertheless, preliminary

TABLE I—CORRECTION FOR VARIABILITY OF RECORD

Century	Curve (1) DRYNESS RATIO* $d = 100\frac{D}{\bar{R}}$	Curve (4) REGIONAL INFORMATION* n	Curve (1a) "DRYNESS" (corrected) $d - df$ where $f^2n = 5$	Curve (1a) RAININESS INDEX $7 - \frac{d(1-f)}{10}$
B.C.				
2	175	15	73	+0
1	144	13	55	+2
A.D.				
1	236	12	85	−2
2	144	66	102	−3
3	77	68	56	+1
4	154	37	97	−3
5	65	74	47	+2
6	129	58	92	−2
7	94	124	75	+0
8	86	116	68	+0
9	83	186	70	+0
10	96	262	83	−1
11	71	264	61	+1
12	67	389	60	+1
13	86	368	76	−1
14	66	564	60	+1
15	69	351	61	+1
16	73	435	65	−0
17	87	561	78	−1
18	103	632	94	−2
19	93	410	83	−1

*According to Yao.

studies have shown the rainfall deviations of different parts of China are related in different ways to world weather, whilst many of the spring floods are thaw floods and associated not with rains but with cold winters. It is probably significant that the three centuries selected as "wet" were ones in which civil strife allowed the canals to fall into disrepair as shown in curve (11), Fig. 4.

The need is clearly for smaller units not only of space but also of time. In the latter respect Yao's tabulations by quarter-centuries yield curve (8) (Fig. 3), which is probably the most significant of all the curves. This curve is derived from the data in Yao's Tables V and VI, but his regional and provincial data are published by him for periods of at least a century. Regional studies of river floods are being made, the most important being that of the Hwang-ho by Shen[10] and Kohler[11], that of the lower Yangtze-kiang by Cheng[12] and Chatley[13],

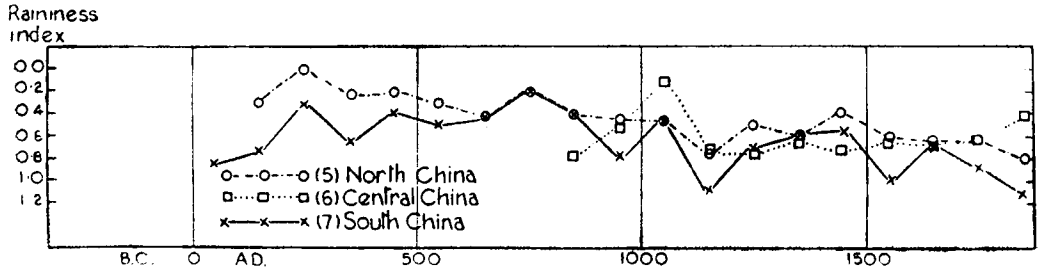


FIG. 2

and of Shensi by Ting[14]. It is anticipated that chronologies on the lines of C. E. Britton's work for England[15] will soon become available for different cities and provinces; thus a study of Peking's climate for the past two centuries has been made by T. C. Cheng[16].

China's north-west passage between the Tibetan plateau and the Gobi desert, also known as the Jade Gate or the Silk Road, is the one gateway to central Asia. A graph indicating the fluctuations of travel along this route is given as curve (9). Whilst the main features of such a curve must necessarily remain partly subjective, the details are based on many hundred archæological and historical sources and it was drawn before knowing Yao's results. Another such curve based on travel in the Syrian desert (Grant[17]) is also given as curve (10). The units are arbitrary.

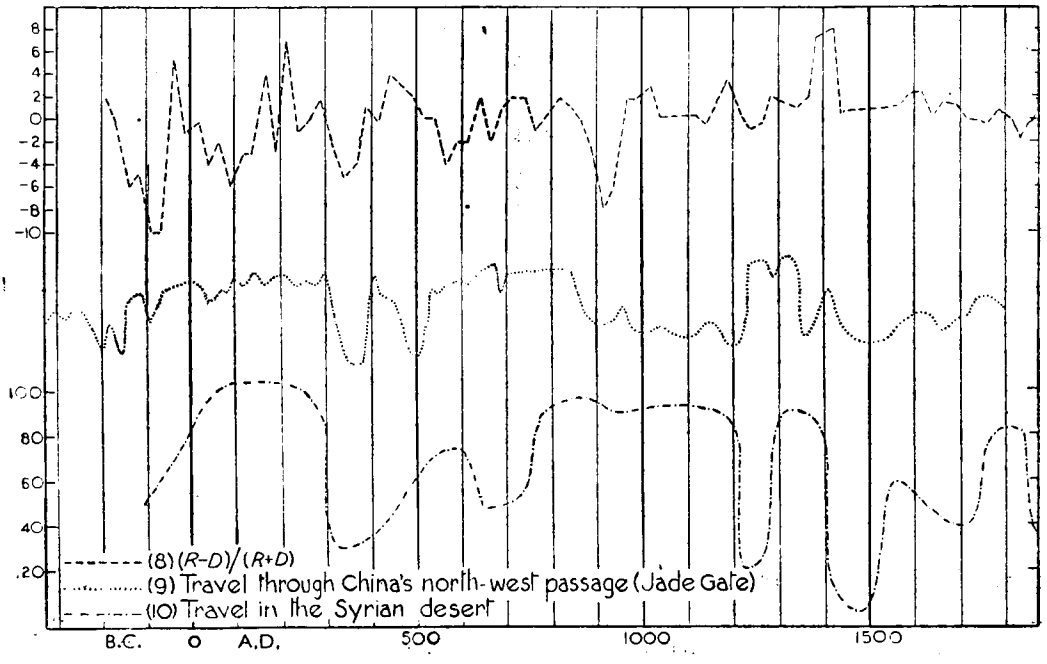


FIG. 3

The late Prof. Huntington, originally in a book " The pulse of Asia " and more recently in an illustrative graph[18], stated that the wet periods in world history are those such as the fourteenth century, when Asiatic and Syrian desert trade was high, Irish civilization low and growth of trees at a maximum. Nevertheless, the disagreement between the curves given here extends equally to curves for tree-ring growth, and other climatic curves. In particular, Huntington selects the seventh century as the driest on the evidence of lakes and ruins in Asia; this is however the very century when central Asian travel broke all previous records, when Christians, Zoroastrians, Manichæists and Moslems passed to and fro across the Tarim Basin. On the other hand the abandonment of many sites has been traced to the early fourth century which does appear to have been remarkably dry and was certainly marked by great southward migrations across China.

Curve (11) (Fig. 4) shows the civil wars and is based partly on J. S. Lee's chart of internecine warfare (reproduced by Yutang[19]). Such strife affected the dyke system and crops inside China and also travel along the silk road outside.

Curve (12) is an attempt—in accordance with a suggestion of Dr. C. E. P. Brooks—to represent the population movements in north China between the Steppe and the Sown. It is however easy to list specific nomad incursions (see Toynbee[20] or the map by Griffith Taylor[21]—whose dates are indicated by crosses below the curve) but sometimes the real population movement was in the reverse direction. In the thirteenth-century Mongol incursions, for instance, settlers went from the Sown towards the Steppe. Population dot maps, such as published by Bielenstein[22] based on early data, are invaluable, but archæological research shows that such information is too erratic in the north-west to use in a graph. A combination of various lines of evidence was used in the preparation of curve (12) but it will need revision in the light of future archæological research (see Stein[23]).

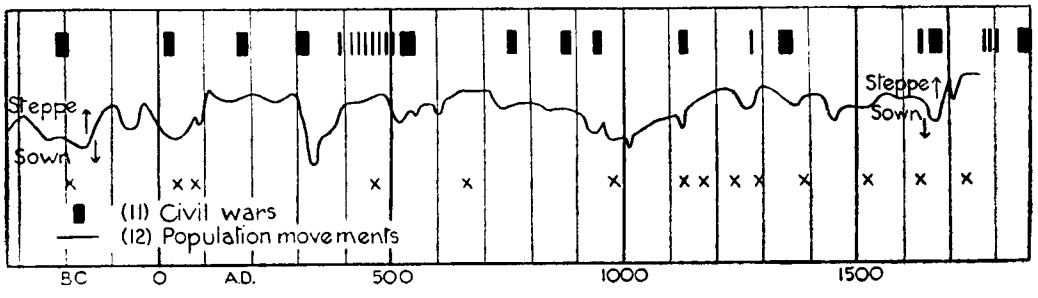


FIG. 4

In his 1944 paper, Yao stresses the limitations of the basic data in both his sources and says of the encyclopædia that, whilst it is a " convenient starting point ", it is " adequate only for very general purposes ". Nevertheless, as he has deposited the complete list of floods and droughts (with two microfilm copies) in the Pennsylvania University Library, his work is an excellent base from which more detailed investigations can be made. Another independent list of floods and droughts, used by Cheng[12], was published in Volume 7 of the Nanking Chinese Library *Annual Bulletin*, but that does not appear to be available in this country.

Summarising, curves (4), (9), (10) and (11) are generally reliable, curves (8) and (12) partly so. The remaining curves are interesting, but we must await independent lines of evidence before we can judge their significance. A further review of the same data can then be made.

In conclusion I should like to thank Dr. C. E. P. Brooks, Dr. Herbert Chatley, Dr. Coching Chu and Professor H. H. Dubs for useful suggestions.

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METEOROLOGICAL OFFICE DISCUSSION

October 25, 1948. On the distribution of temperature and wind in the upper westerlies, by E. Palmén (*J. Met., Lancaster, Pa.*, **5**, 1948, p. 20). Opener—Mr. J. M. Craddock.

Mr. J. M. Craddock stated that Palmén's line of attack had been to examine a series of vertical cross-sections through the atmosphere along the meridian of 80°W. The 16 upper air stations on or near this line gave information adequate for the analysis of fronts, tropopauses and inversions, besides the isotherms, but that the analysis of upper winds normal to the plane of the cross-section was based on computed slopes of isobaric surfaces and on the assumption of geostrophic or gradient air flow. Thus in view of the, not negligible, observational error of the radio-sonde and the difficulty of determining the curvature of the air flow, the exact wind structure at a particular time could not be determined although the general picture was clear enough. From a series of charts covering the winter of 1946–47 Palmén reached the following conclusions as to conditions characteristic of an upper trough (but applicable also in other situations).

(1) The tropopause could not be considered as a continuous surface of discontinuity of lapse rate, but that three different tropopauses could be traced, characterised by quasi-entropy. Palmén's illustrative cross-section was not conclusive, but in work with more extensive data in a later paper he had put the matter beyond doubt.

(2) The arctic stratosphere in the time of no insolation was always very cold—at the 200-mb. level the temperature field shows a cold arctic zone, with a warmer ring between 45° and 65°N., a second ring of low temperature south of the jet stream, and then increasing temperature south to the equator.

(3) Often there is a region of lowest temperature in the troposphere and highest in the stratosphere in latitudes 45–65°N. Mr. Craddock thought that

while this distribution was characteristic of the later stages of an active depression near the line of the cross-section it was not prevalent in other synoptic situations, and should be looked on as rather exceptional.

(4) The contrast in temperature between the equatorial and polar regions is in the mean troposphere and largely concentrated in a rather narrow band, which is also the zone of strongest westerlies. Mr. Craddock considered this an important and very common feature of the upper circulation, although the wind belt often departed from the westerly, and tended to be wider and less intense over the eastern North Atlantic and British Isles than over North America. In many major cold or warm outbreaks the wind belt formed a sinuosity which is liable to separate, as a closed pool, to south or north of the main belt.

(5) The strongest west wind, exceeding 80 m./sec. in Palmén's example, can regularly be observed vertically above the latitude where the polar-front layer reaches the height of 600–500 mb. Below this level the horizontal wind shear is rather weak, and above this belt the air moves as a narrow " river " with the strongest speed in the tropopause level. This zone of wind can be characterised as a " jet stream " embedded in the upper westerlies. The illustrative cross-section did not, in the absence of actual wind observations, establish the existence of this feature beyond doubt, and Mr. Craddock produced a cross-section crossing the British Isles in which a jet stream could be identified from the observed wind values. He thought that the jet stream bore a less definite relation to the surface polar front than Palmén suggested and that a jet stream over the British Isles was often north-westerly or even northerly.

Palmén examined the dynamic stability of the air flow in the zone of anticyclonic wind shear to the south of the centre of the jet stream. The shear of the geostrophic wind exceeded the limit below which the air flow was dynamically stable, but he was unable to ascertain beyond doubt whether the actual wind did so. After further consideration in a later paper he concluded tentatively that except possibly in zones less than 300 Km. wide, the shear did not exceed the critical value.

Finally he showed that, where a warm air mass with strongly anticyclonic wind shear was adjacent to a weak front, the latter might show anticyclonic shear at the 700-mb. level.

Commenting on the paper as a whole, Mr. Craddock said that three features, the multiple nature of the tropopause, the cold polar stratosphere at mid-winter, and the concentration of the thermal gradient between equator and pole into a fairly narrow band were important descriptive features of the winter circulation. The jet stream was the feature most likely to arouse controversy, and one very important to the forecaster. The eastern part of North America in winter was a very favourable position for its development, because the geographical distribution did not impede the near approach of warm and very cold air masses. Over the British Isles a jet stream was most likely to arise when there was cold air over the continent and warm over the Atlantic. Upper westerly winds of very high velocity were also regularly observed over north India in winter. As to the theoretical significance of the jet stream, Palmén's conclusion to a later paper may be quoted. "A definite explanation of the temperature field and the extremely strong latitudinal change of shear (and vorticity) has still not been found. It is obvious that the appearance of the very strong westerly

current in the upper troposphere, the formation of a distinct frontal zone below and the characteristic temperature field at the tropopause level are phenomena related in some fashion."

Sir Nelson Johnson opened the discussion by asking how a forecaster could recognise the presence of a jet stream.

Mr. Durst said that as soon as it was realised how important the phenomenon might be in navigation an investigation was put in hand to see how jet streams behaved over the British Isles. The result was a paper which was coming before the Meteorological Research Committee. On the whole the tendency was for jet streams to lie north-west to south-east rather than west to east; they were quite common somewhere or other on the synoptic charts of Europe and the North Atlantic; they were of the order of a thousand miles in length and three or four hundred miles in width. On the polar-air side of the centre of the jet the spatial rate of change in wind speed was very great, sometimes the wind speed fell from 130 kt. to 30 kt. in a hundred miles. The importance to navigation was obvious and was emphasised by the recent case of the Vampires flying to Iceland when the frequency of equivalent head winds had been calculated on the assumption that wind speeds were as likely to fall off down wind as across wind. This was not true with jet streams. The frequency of very strong equivalent head winds were vitiated but the frequency estimated for the moderate or strong winds was not materially affected.

Mr. N. E. Davis said that jet streams over the British Isles generally arose when polar air flowed south and south-east round a high-level low over Norway and tropical air flowed north-east and east round an extension of the Azores anticyclone, the resultant jet stream being NW. As the slope of a front depends on the difference in wind speed parallel to the front, as well as inversely on the difference of temperature, the front associated with a jet stream gets very steep in its upper levels. This accounts for the extreme horizontal-wind-speed gradient on the polar side of the jet.

Dr. Sutcliffe remarked that these facts about the atmospheric circulation were of first-rank importance, so important that we may be in danger of being carried away by the jet stream, as though it were a new phenomenon not in accordance with known facts and principles. We were, however, familiar with the high-level circulation being generally more vigorous than the low-level and that the high-level geostrophic wind is mainly the thermal wind. Thus, if we think of the atmosphere as a baroclinic fluid with relatively small temperature gradients at both high and low latitudes, we should expect the temperature profile to be represented by an inflected curve with a maximum slope corresponding to a maximum westerly wind at high levels. The only surprising thing was the intensity of this maximum in the cases examined, but his own impression was that there were wide variations and that to accept the idea of a jet stream encircling the earth " like a meandering river " we must be prepared to extend the term to weak maxima which themselves would never suggest the term. The essential accompaniment of a jet stream is a strong thermal gradient, a concentration of solenoids, and this will tend to be built up in any generalised frontogenetic region.

We must, however, recognise a real discrepancy between the temperature and wind structures now observed and those associated with the classical polar-front hypothesis. Instead of a gently sloping Margules surface containing most

of the solenoids in a virtual discontinuity we seemed to have a more nearly vertical zone of large thermal gradient in the upper levels with two regions of strong wind shear, one on the cold side and one, anticyclonic, on the warm side. On dynamical grounds it seemed easier to explain this mode of organization of the motion than that of the single sloping frontal surface when we remembered that the strong thermal gradients were continuously being set up in one region and destroyed elsewhere. A frontogenetic process, as in the classical hyperbolic pattern, would tend to concentrate the isotherms, at all levels in the troposphere, in a more or less vertical zone. The necessary modification of wind to pressure gradient implied a flow of air across the upper isobars from the warm to the cold side. This implied also upper divergence (and anticyclonic vorticity) on the warm side, convergence (and cyclonic vorticity) on the cold side. The low-level motion, to complete the cycle, must show convergence to the warm side and divergence to the cold side, in effect an undercutting by the cold air. It seemed likely that the sharp surface front on the warm side of the jet stream was the result of this convergence. On this basis the jet stream itself was transitional air in the zone of strong thermal gradient and it must be rather arbitrary to connect the low-level frontal surface on the warm side of the transition zone with the upper convergence region on the cold side.

It was, however, easy to give plausible comments on observed facts: the merit lay, as so often in meteorology, with those who make the discoveries; and these discoveries were vitally important. As practical synoptic meteorologists we must review our techniques, consider whether we can, by more careful drawing of contour charts, represent more accurately the facts so easily smoothed out. Possible ideas would be to try to run a line of maximum gradient through the upper contour patterns, to represent the intensity of the jet stream by some "jet index", and to attempt to give the forecast position and index in our forecast charts. Information over wide areas may be inadequate but general judgment using models based on cases where data are adequate is the normal technique of all analysis and should not be inapplicable to this aspect.

Dr. G. D. Robinson said that Professor Palmén's results indicated a change of velocity of the order of 100 m.p.h. in 300 miles, whereas Mr. Durst's investigations showed a change of this order in 100 miles. These distances are of the same order as the separation of stations used in the respective investigations. May they not therefore indicate the "resolving power" of the radio-sonde network rather than a real wind structure, and can we say that an increase of this resolving power would not demonstrate a wind discontinuity similar to that expected at the old-fashioned frontal surface? We should not forget that, compared with surface observations, upper air observations are extremely meagre, and that observational techniques and the lack of continuous records at a fixed position tend to mask sudden changes and to smooth discontinuities.

Mr. J. S. Sawyer remarked that Palmén's intention was to study the zonal atmospheric motion. The jet stream appeared above the polar front in latitude 30° to 40°N. and similar phenomena were found above fronts elsewhere; on the other hand, maps of the mean circulation show a strong belt of upper westerlies in subtropical latitudes, but whether these show the same features elsewhere as on the American coast is not known. However, the term jet stream has been applied to both the local frontal phenomena and the broad feature of the hemispherical circulation; there is thus a risk of confusion.

Mr. Bannon pointed out that the jet stream is associated with strong horizontal temperature gradient and that he had found that, around Britain, with any well marked front there was an associated jet stream of greater or less intensity. It was of interest that, in November 1947, a jet stream occurred over or near the British Isles on 16 consecutive days. He also pointed out that the gradient of wind across the stream was not necessarily a true measure of the horizontal shear (as had been assumed by previous speakers) because of the possible curvature of the stream lines.

Mr. C. K. M. Douglas remarked that the existence of very strong currents at cirrus levels in belts a few hundred miles wide more or less parallel to a major front had long been recognised. Recent observational advances have led to a more detailed knowledge of the structure of these currents.

A suggestion had been made that the Central Forecasting Office smoothed upper contours too much. This is not altogether avoidable in the case of forecast contours, especially 24 hours ahead. When large changes are in progress it is difficult to fix the exact future position of a jet stream, which does not necessarily remain at a fixed distance from the associated front especially when cold air is subsiding and spreading out.

Mr. B. C. V. Oddie said it was somewhat alarming that this important phenomenon has evidently been known vaguely to many forecasters for some years without coming to light. It was first brought to his notice in 1945 when a NOCTURNAL aircraft was carried nearly 100 miles from its expected position while flying above a cold front. Since then he had made a practice of indicating in route forecasts a narrow belt of strong winds parallel to and above a front. These forecast winds must have been very inaccurate, but at least warned navigators against assuming the winds over a front to be merely intermediate between those on either side.

Mr. Dight, agreeing with Dr. Sutcliffe's cautionary note, said that these high-speed winds were recognised and had been indicated to forecasters on practical training courses for a long time. The advice was that the winds probably occurred only in a narrow belt and did not appear to persist for long over a given locality, points for consideration when forecasting for long- or medium-range flights. The tentative explanation given was the " bunching " of the isotherms in the upper air frontal zone, usually with the distribution suggested by a previous speaker giving NW. to N. winds over Britain.

Dr. Belasco wondered to what degree the horizontal temperature gradient influenced a jet stream and referred to upper-air conditions over the British Isles at 0600 on February 8, 1946, when a quasi-stationary warm front extended westwards from Belgium to Ireland. Whereas the wind direction (between 280° and 290°) at all stations in the warm air rapidly increased with height in the layer from about 450 mb. through the tropopause to above 200 mb. (e.g. at Downham Market from 77 kt. at 500 mb. to 198 kt. at 170 mb.) the temperature gradient normal to the front above 400 mb. became reversed. Thus in the same air mass the temperature difference between Downham Market and Lerwick at 0600 was +21°F. at 400 mb. and −16°F. at 170 mb., between Brussels and Leuchars at 1200 was +17°F. at 400 mb. and −15°F. at 200 mb. and between Liverpool and Stornoway at 0600 was +10°F. at 400 mb.

Dr. Belasco said he had found the temperature contrast between subtropical and polar regions in the troposphere greatest about midway between them and quoted from his thesis on " The temperature characteristics of different classes of air " (1947) that, along about 10°W. the difference between the mean temperature of tropical and direct polar air at 450 mb. in winter is 50°F. between 51°N. and 57°N.

Mr. T. H. Kirk remarked that like many other ideas in meteorology, that of the jet stream derives from oceanography. Ocean currents, of which the Gulf Stream is the best example, are analogous to the jet streams of the atmosphere. The dynamical problem must be simpler for ocean currents inasmuch as stationary fields can be assumed. Rossby has already given some account of the problem in his paper " The dynamics of steady ocean currents ".

The Gulf Stream, together with its extension, the North Atlantic Drift, maintains its identity over thousands of miles, and we have heard that jet streams can exist over comparable distances. The very mechanism of self-maintenance over such distances constitutes a real dynamical problem. Another aspect which is important derives from the existence of a velocity profile across the jet stream. This means that we must look for an explanation elsewhere than on the usual equations of motion for frictionless flow.

Mr. Sumner thought that its connexion with dynamic instability was of greater interest. If dynamic instability is ever reached it will be realised at one height only and over a limited area; the shearing across the layers above and below make eddying probable which, once started, would infect a wider and deeper layer downwind. If this is so then first it might explain the severe bumpiness sometimes met at great heights by aircraft even in clear air and secondly why the Rossby effect of anticyclogenesis to the right of a strong westerly current due to lateral shear stresses does not seem to work very often. To produce an anticyclone and not simply subsidence larger eddy viscosities than normal may be required.

Palmén remarks that mean charts do not show a jet, which reminds us that the general circulation is not simply the mean circulation of the atmosphere. A climatic mean does not represent a physical reality, and, since the equations of motion are non-linear, the mean circulation does not represent a real process. The jet stream is one of the features which is meaned out of existence. Mr. Sumner could not offer any explanation: to him, the confluence of stream lines seemed only to explain local tight gradients; however the subsidence associated with anticyclonic vorticity may maintain a tight thermal gradient all the way round the periphery of a warm ridge in spite of the tendency of lateral mixing to reduce it.

Mr. G. J. W. Oddie referred to the theory put forward in earlier papers by the Chicago University Group regarding the extent and direction of the jet stream. According to this the jet stream marked the transitional belt between the régime of the polar cap in which the westerly component of the wind increased towards the equator owing to a tendency for lateral mixing to produce uniformity in the vertical component of absolute vorticity, and the régime of the equatorial belt in which the westerly component of the wind increased towards the pole, owing to a tendency for lateral mixing to produce uniformity of absolute angular momentum. The jet stream would thus be expected to encircle the globe in middle latitudes meandering northward and southward

as the relative activity of the two régimes varied. Circumpolar upper-air charts included in these papers had shown four or five complete waves round the earth between 30° and 50°N., the direction of the stream varying from S. through W. to N. Another interesting suggestion appearing in these papers had been that increased velocities in one wave could lead to the by-passing of the next which was then isolated as a " warm high " if on the north side of the stream or as a " cold pool " if on the south side. Mr. Oddie asked if all these ideas had been dropped in the latest papers. With reference to Mr. Craddock's suggestion that more had been drawn into Palmén's cross-sections than the observations justified, Mr. G. J. W. Oddie asked if we could not assume that Palmén had worked, not from one set of synchronous soundings, but from a series of sets.

Mr. D. G. Harley pointed out that if an aircraft crossing the Atlantic meets a jet-stream wind head-on and unforecast, the result may be fatal. London, Prestwick and Shannon airports have to forecast these winds on the other side of the Atlantic up to 24 hours ahead. The thermal-wind idea is still most useful but leads to considering the upper winds as secondary to the surface situation. We need to develop new methods of forecasting from our new knowledge of the upper circulation, but cannot just suddenly drop the present methods based on long experience of surface conditions. The concept of momentum—masses of air in motion—is most important.

Commander Frankcom hoped that steps could be taken to introduce this subject at a discussion at the Institution of Navigation. The discussion had emphasised the necessity of a reasonable network of observations and this probably applied particularly to the Atlantic Ocean where long-distance air traffic was so heavy. Possibly the existence of 13 ocean weather stations would ensure detection of such high-velocity wind zones. This might provide a good argument in favour of the retention of weather ships, when the situation is reviewed by I.C.A.O. next spring.

Mr. R. T. Andrews said there was evidence for periods of very strong upper currents (for which he did not consider " jet stream " a very suitable term) in the nephoscope observations contained for many years in the *Daily Weather Report.* He was very doubtful whether the normal direction of the jet stream over the British Isles was north-westerly and thought it was more frequently westerly. He also doubted if it occurred as a belt right round the hemisphere and suggested it was both narrow in width and limited in length, being normally concentrated on the south side of a cold pool.

In reply, *Mr. Craddock* said that the term " jet stream " seemed to be used to cover two things, a zone of more or less intense thermal gradient, which often extended round the hemisphere, and secondly, the narrow zone of extremely high winds near the tropopause level which sometimes accompanied an intense thermal contrast. He thought that the term should be restricted to the second sense, in which Mr. Durst had used it. In reply to Dr. Belasco he said that his example was most interesting, but that the stations of Downham Market and Lerwick were too far apart for use in estimating the local temperature gradient near Downham Market. In reply to Mr. G. J. W. Oddie (partly communicated) the basic theory mentioned was not used in the present paper, but the cutting off of warm and cold pools is a common occurrence of obvious importance in the general atmospheric circulation. He did not know whether

any satisfactory explanation had been published. Regarding Palmén's technique, the use of a series of cross-sections would confirm the general picture, but would not establish in an individual cross-section a feature liable to rapid fluctuations (such as a local wind maximum, or a tropopause) if the synchronous data were inconclusive.

METEOROLOGICAL RESEARCH COMMITTEE

The third meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on November 4, 1948. Methods of attacking the problem of forecasting fog were discussed; officers at outstations who have volunteered to assist in fog investigations will form a working party under Dr. Sutcliffe to tackle this problem.

The direction of research in extended forecasting was also discussed and it was decided that for the next year, at least, the available effort in the Forecasting Research Division should be concentrated on the medium-range problem (i.e. forecasts for 4 to 5 days ahead) which may be tackled by an extension of present forecasting techniques and whose study should prove very useful when the problem of forecasting for much longer periods comes to be considered.

Other matters discussed by the Sub-Committee were statistics of wind, the phenomenon known as a "jet stream" and a mathematical method of analysing pressure fields suggested by Professor Sperner as an approach to the long-range forecasting problem.

OFFICIAL PUBLICATIONS

The following publication has recently been issued:—

Cloud Forms, 6th edition.

This publication gives a detailed description of the internationally agreed classification of cloud types revised to agree with the decisions of the Washington Meteorological Conference of 1947. It gives at least one and often three photographs of each type of cloud. Readers familiar with the earlier classification should note that important changes have been made, especially in the classification of low clouds. This is the first publication to give an illustrated description of the new classification.

ROYAL METEOROLOGICAL SOCIETY

The meeting of the Society, held at 49 Cromwell Road, on November 17, Dr. G. M. B. Dobson in the Chair, was devoted to a discussion on the physics of clouds, and was concerned almost entirely with ice particles.

The discussion was opened by Mr. Ludlam, who outlined recent work on atmospheric ice nuclei and its application to the interpretation of cloud forms and transformations. The old conception of sublimation nuclei (solid, insoluble particles isomorphous with ice and allowing condensation direct from vapour to crystal at ice saturation) was introduced by A. Wegener, and developed by Findeisen. In 1939 Krastanow, however, attacked the problem on a sounder theoretical basis, and emphasised that such solid particles as occur

in the atmosphere obtain microscopic skins of adsorbed water at high vapour pressures and tend to produce supercooled droplets rather than crystals even at temperatures far below 0°C. Krastanow suggested that atmospheric ice crystals originate when these particles promote the freezing of already-formed droplets. Weickman subsequently discovered that ice crystals could be grown at high ice supersaturations only in very small numbers, whereas they appeared readily and plentifully on approach to water saturation. He concluded that ice nuclei first cause the condensation of vapour into liquid and then allow the liquid to freeze; he therefore called them " freezing-nuclei ". Rau examined the freezing of supercooled droplets by atmospheric freezing nuclei and found that after several actions each became ineffective until the supercooling reached −33°C. Findeisen used a large cloud-chamber to investigate the effect of rate of expansion (corresponding to rate of ascent of damp air in the atmosphere) on the behaviour of ice nuclei, and discovered two classes of nuclei. Those of the first class were characterised by their rarity (1 or less per litre of air) and efficiency (acting at temperatures below about −7°C.), and were less effective the higher the rate of expansion; those of the second class were relatively very numerous, but produced crystals only below about −32°C., and acted a little more readily the more rapid the expansion. Mr. Ludlam suggested that nuclei of the first class acted by allowing an adsorbed water film to freeze and thus produced an ice nucleus which grew by sublimation; and that with a high rate of expansion this ability was swamped when a consequent high supersaturation at the time of cloud formation involved the nucleus in droplet production, so that it then became a nucleus of the second class by causing the droplet to freeze when the temperature fell towards −33°C.

Mr. Ludlam then applied these results to the interpretation of cloud forms. In consequence of the time taken by ice particles to grow to an appreciable size and the short life of individual parts of cumulus, these clouds have to exceed the level at which ice particles originate by an amount depending upon their liquid-water content before they become transformed into cumulonimbus and the ice particles develop into precipitation. In very cold weather cumulus have very small liquid-water contents and do not produce showers until their summit temperatures have fallen to about −20°C. Mr. Ludlam also mentioned that the conditions inside cumulonimbus did not correspond to those assumed in the older theories of thunderstorm charge generation. He had been able to show that even at temperatures of −20°C. or −30°C. the larger precipitation elements were likely to have liquid skins, but that when the cloud tops reached above the −32°C. isotherm and the nuclei of the second class produced relatively large numbers of ice particles, these grow predominantly as wholly solid structures. Findeisen has given a new theory of charge generation which implies that the principal charging is associated with these solid structures, and Mr. Ludlam suggested that thunderstorms may occur only when the temperature of the cloud top falls below −32°C.

At temperatures between about −10°C. and −30°C. clouds usually contain both water and ice; at the higher temperatures the ice particles fall out and the water cloud survives, but at the lower temperatures the ice particles are more numerous and it is the droplets which disappear. At temperatures of about −40°C. ice clouds are rarely seen to possess mother-(water-)clouds, but are still to be regarded as a type of *fallstreifen*. Mr. Ludlam illustrated these points with some photographs.

M. Dessens of the Observatory of Puy de Dôme described how he had captured haze droplets upon fine spiders' threads and identified them with condensation nuclei. He hoped soon to be able to examine visually their behaviour at low temperatures.

Dr. Fournier d'Albe then described some experiments with a cloud chamber, which by employing smaller expansions more nearly imitated atmospheric processes than most apparatus of this kind. He found that in outdoor air ice crystals first appeared within the chamber-fogs when the temperature had fallen below −32°C., and that they then numbered not more than about 20 per cm.^{3} At temperatures below −41°C. many more crystals appear, but only when the air is cooled to the dew point (not the frost point, even though no droplets may be detected). Artificial nuclei of sodium chloride produced droplets at temperatures above −41°C., but silver iodide provided true sublimation nuclei active at temperatures up to about −7°C. and at ice saturation.

Mr. Palmer emphasised that the nuclei important in rain production probably number less than 10 per litre and escape notice in an expansion chamber of ordinary size. He constructed in the Clarendon Laboratory a chamber in which about 5 litres of air could be examined for nuclei, and was then able to detect these rare nuclei and to show that their concentration varied from day to day. Using a smaller apparatus in an aircraft he had found that the ice nuclei acting at −32°C. at ground level were absent from the air above the lowest inversion or haze top.

Dr. Frith mentioned some unsolved problems, and remarked that although ice supersaturation in clear air might be expected to occur commonly, it had rarely been observed by the Meteorological Research Flight.

Dr. Dobson remarked that the latest results seem to indicate that the behaviour of ice nuclei varied with the duration of their exposure to changing conditions, and thanked all the speakers for contributing to such an interesting discussion.

ROYAL METEOROLOGICAL SOCIETY

Popular lectures

Some eminent meteorologists have very kindly consented to lecture on popular subjects expressly designed to interest amateur Fellows of the Society. These lectures will take place at monthly intervals throughout the coming session at the Science Museum Lecture Theatre, Exhibition Road, South Kensington. Visitors will be welcome.

The first lecture was given by Prof. Brunt, F.R.S., on November 10, on the subject "Where to live—a meteorological problem", and on December 3 there was an exhibition of a number of films designed to illustrate the wide scope of meteorology and the use of the ciné-film technique for instruction and research in this science.

Later arrangements will include the following lectures, each at 6 p.m.:—

January 12, 1949: SIR GEORGE SIMPSON, K.C.B., F.R.S.; Atmospheric electricity during the last 50 years—Sir Robert Watson Watt, F.R.S., in the Chair.

February 10, 1949: SIR NELSON JOHNSON, K.C.B., D.SC.; Some international aspects of meteorology—Mr. E. Gold, F.R.S., in the Chair.

March 3, 1949: PROF. GORDON MANLEY, M.A., M.SC.; British climatic fluctuations since Queen Elizabeth's day—Mr. Ian Kirkpatrick in the Chair.

April 6, 1949: DR. G. M. B. DOBSON, F.R.S.

May 5, 1949: MR. E. GOLD, C.B., D.S.O., F.R.S.

LETTERS TO THE EDITOR

Formation of rain

In the October 1948 issue of the *Meteorological Magazine* Mr. A. C. Best requests that reports of substantial rain associated with cloud tops below freezing level be forwarded to you. The following reports were compiled whilst I was Meteorological Officer in the Seychelles Islands, approximate position 4°30'S. 50°E. and are based on data supplied by the crews of a Catalina Ferry Flight operating from Mombasa to Seychelles.

Date	Time	Position	Cloud tops and precipitation
	G.M.T.		
5.12.45	0900–1100	5°S. 50°E. to Seychelles	Aircraft flying at 10,000 ft., encountered cumulus bank, tops 8,000–12,000 ft. and descended to 1,000 ft., beneath the cloud, where heavy to moderate showers were encountered.
12.12.45	0900–1130	5°S. 48°E. to Seychelles	Aircraft flew at 7,000 ft. and over cumulus cloud, tops 5,000–6,000 ft., and then descended below cloud where light to moderate showers were encountered.
2. 1.46	0500	4°30'S. 41°30'E.	Aircraft when flying at 9,500 ft. encountered cumulus tops 7,000–8,000 ft. which, on descent, were found to be giving rise to moderate showers.
12. 1.46	0900–1100	5°S. 51°E. to Seychelles	In this area 7–9 tenths cumulus cloud, base 1,200–1,500 ft., tops 7,000–10,000 ft., were giving rise to moderate to heavy showers, which at the Seychelles observing station were considered to be of sufficient importance to justify sending two deterioration reports to the mainland.

It should be noted that the terms "light", "moderate" and "heavy" showers are used in the tropical sense of the word, and thus a moderate shower would mean a reduction in visibility from 20 miles to 1–2 miles in a very short space of time and in a heavy shower the visibility even on the ground is often reduced to half a mile.

In compiling the above data I have been very careful to exclude all cases when there was any medium cloud present or when there was any doubt as to the top of the cloud and nature of precipitation below the cloud. The period during which the reports were made was that of the NW. monsoon (NE. monsoon of India) and thus on many occasions both medium cloud and cumulonimbus were reported, and if such were the case then any reports of precipitating cloud with a top below freezing level have been ignored even if the cumulonimbus and medium cloud were far distant from the track of the aircraft.

The average temperature reported by aircraft when flying at 10,000 ft. was 11–12°C.

T. L. HUNT

Bawtry, November 2, 1948

The green(?) flash(?)*

All my life I have looked, as opportunity offered, for the so-called green flash; I had conspicuously failed to catch it. To-night, over the smooth water of the Red Sea, I have seen it.

I now know the main reason for my previous failures; my conception of what I was looking for was at fault. I had expected something green—and pictured emerald green; I had expected a flash, i.e. something momentary like lightning, whose duration was no more than that of the well known persistence of vision; and I had expected something extending perhaps 20′ or 30′ above and around the sunset point. It was none of these things.

The sun set in a rosy sky, so that the light-sensitive cells of my eyes were saturated with red light—a prerequisite to the observed complementary colour reaction. Just after the last trace of sun had disappeared—say within a second—a small irregularly defined patch of bluish-green light perhaps 6′ long (one-fifth of the sun's diameter) and a minute or so high developed (that is the best word I can find for a non-instantaneous phenomenon) on the horizon around the sunset point, and, perhaps in another second, collapsed (this word does not suggest instantaneous extinction).

I was so taken by surprise at my success in seeing what had previously eluded me, that it was a second or two before I realised that this was the green flash; hence my description of dimensions and times may be somewhat imperfect. The biggest shock came from the fact that the colour was not emerald green, but could more fairly be described as bluish green; secondly, the smallness of the whole effect was contrary to my expectation. At the next opportunity, I shall know better what to look for.

The colour, dimensions and duration, being purely physiological, may easily vary with individuals, with the extent of the previous fatiguing of the red-sensitive cells, and with the sharpness of the actual sunset. This latter in turn could depend on the smoothness of the horizon, since a swell could allow lingering shafts of light to reach the eyes just as the mountainous edge of the moon gives rise to the " Baily's Beads " effect at a total solar eclipse.

L. J. COMRIE

R.M.S. Stratheden, Red Sea, June 25, 1948

NOTES AND NEWS

Special long-service awards

"A pleasant little ceremony took place in the Conference Room at Victory House on November 12, 1948, when the Director of the Meteorological Office, Sir Nelson Johnson, K.C.B., D.Sc., presented suitably inscribed barographs to two Merchant Navy captains in recognition of long and meritorious service as voluntary meteorological observers at sea. Capt. W. G. Higgs, O.B.E., Commodore of the Port Line Ltd., and Capt. R. P. Galer, C.B.E., R.D., R.N.R., of the Clan Line, were the recipients of these awards, and the ceremony was attended by the Marine Superintendents of the Port and Clan Lines respectively, and senior officers of the Meteorological Office.

*Reprinted, by permission, from the *Journal of the British Astronomical Association.*

Similar presentations were made, on behalf of the Director, by the Marine Superintendent, Commander C. E. N. Frankcom, to Capt. J. E. Wilson, O.B.E., Furness Line, aboard the *Nova Scotia* at Liverpool on October 12, 1948, and to Capt. W. H. Downing, Manchester Liners Ltd., aboard the *Manchester Progress* at Manchester on December 1, 1948.

Tornadoes in Ireland

Thanks are due to Miss C. M. Botley for pointing out, with reference to the tornado in Co. Kildare mentioned in the November 1948 number that an account of a tornado in Dublin in 1850 was published in the December 1929 number of the Magazine.*

Other records of Irish tornadoes have been received from Mr. F. E. Dixon of the Irish Meteorological Service, as follows:—

(*a*) September 4, 1767, at Santry near Dublin when a marquee with people in it was lifted in the air (*Dublin Journal*).

(*b*) October 5, 1851, at Limerick, roofs stripped of slates, boats lifted from the water, shattered windows blown outwards, large rafters found 200 yd. from a shattered roof, damage track less than 100 yd. wide.†

(*c*) Small one 15 yd. in diameter, August 16, 1941, near Camick-on-Suir when houses were unroofed and haycocks lifted.

Royal Geographical Society

Prof. C. G. Rossby will lecture at the Royal Geographical Society at 5 p.m. on Monday, January 24. His subject will be "Air-mass meteorology—its geographical implications".

OBITUARIES

John Dover, M.A.—It is with deep regret that we announce the death on November 7, 1948, of Mr. John Dover of Totland Bay. An appreciation of Mr. Dover's long association with the work of this Office was included in the July 1948 issue of this magazine.

Oswald Hawkins Latter who died on October 11, 1948, in his 85th year had been senior science master at Charterhouse from 1890 to 1926. On going to Charterhouse he set up a rain-gauge and other instruments in his garden and personally maintained these records up to the day of his death, a period of 58 years.

In addition to a keen interest in meteorology, Mr. Latter was regarded as an expert in biology. He made occasional contributions to *The Times* on the effects of weather on insect life.

REVIEW

The water resources of central Africa, by F. Debenham and *Climate and weather in modern naval warfare*, by Cdr. C. R. Burgess. *Geographical Journal, London*, **111**, 1948, pp. 222–234 and 235–250.

The September 1948 number of the Royal Geographical Society's *Geographical Journal* contains two articles of considerable interest to meteorologists.

*CORLESS, R.; An old weather diary and a tornado in Dublin in 1850. *Met. Mag., London*, **64**, 1929. p. 266.

†GRIFFIN, D.; On the Limerick whirlwind of October 5th, 1851. *Proc. R. Irish Acad., Dublin*, **5**, 1850–53, p. 225.

The origin of the fluctuations in level of the central African Lakes is a long-standing problem. Various theories have been propounded of which for a time correlation with the sun-spot cycle was the favourite. In his paper Professor Debenham gives a detailed explanation of the fluctuations of Lake Nyasa based on the growth of aquatic vegetation and the accumulation of silt in the outlet river.

Commander C. R. Burgess describes the work of the Naval Meteorological Service, Admiralty, on three important problems: (*a*) The extent of the doldrums belt and the weather in it, (*b*) the forecasting of sea and swell on beaches in relation to landing operations, and (*c*) forecasting the position of the edge of the Arctic ice sheet.

G. A. BULL

WEATHER OF NOVEMBER 1948

The month opened with pressure rather high over most of Europe and low to the north and west of the British Isles. A deep depression passed north-eastwards between Scotland and the Faeroes on the night of the 3rd and a much less deep centre south-eastwards across the mouth of the Channel on the 7th. High pressure then spread south-south-east from Greenland and an anticyclone was centred over the British Isles on the 8th. This system soon moved eastwards to the continent, where it remained nearly stationary for several days, while a large system of depressions advanced slowly towards the British Isles from the west. Eventually, on the 15th, a depression developed over Ireland and moved east-south-east across southern England, reaching Belgium on the 16th; it was followed by another which passed eastwards across northern Ireland and southern Scotland on the night of the 17th. Pressure had already begun to rise over central Europe on the 16th, and the anticyclone which soon developed persisted throughout the rest of the month. At one time (around the 22nd) its centre was over the British Isles. There were readings above 1040 mb. in Holland on the 24th and Germany on the 25th.

Mean pressure for the month was above 1025 mb. from the south-west of France across to Hungary and southern Germany, and below 1005 mb. over southern Greenland and the Atlantic to southward. Over most of North America it was between 1010 mb. and 1020 mb. It was above the average over the Mediterranean and practically all Europe south of the Arctic Circle, and above by as much as 10 mb. in north-east France, but was 5 to 10 mb. below normal in the Azores and over a large area of ocean north-west of the Azores. There was also an area with pressure 6 mb. below normal in the United States slightly to westward of the Great Lakes.

In the British Isles the weather of the month was dry on the whole and mild, particularly in the west and north. The week ending on the 20th was notably mild for the season. From the 22nd onward fog developed frequently, particularly in the eastern and Midland districts of England.

During the opening days Atlantic depressions moved north-east along our north-west seaboard, while associated fronts crossed the British Isles. Rain fell fairly generally and was heavy at times locally. Temperature fell appreciably on the 5th when a current of polar air flowed across the British Isles in the rear of one of the main depressions. On the 6th and 7th a shallow depression moved slowly from south-west of Ireland to France; considerable rain fell in southern England and south Ireland on the 6th. Meanwhile a wedge of

high pressure extending south from an anticyclone over Greenland gave mainly fair weather in northern districts of the British Isles. On the 8th an anticyclone over Scotland moved south-east and later turned east to central Europe and was associated with a spell of dry, rather cold weather over much of England. By the 11th a large complex depression over the Atlantic was beginning to affect our western districts and thereafter the air current over the British Isles was drawn from the south and a period of very mild weather ensued. On the 12th and 13th shallow secondaries moving north-east along our western seaboard caused rain in the west and north. On the 15th an elongated depression over Ireland moving east-south-east was associated with a gale in the south-west and rain in most parts, while on the 17th, an Atlantic depression moving rapidly north-east across the country caused further rain, heavy locally in the west. Among the largest falls of rain in 24 hours during this spell were 2·04 in. at Blaenau Festiniog and 2·30 in. at Cwm Dyli, Snowdon, on the 14th and 2·51 in. at Borrowdale on the 17th. On the 19th a very deep depression south of Iceland moved slowly north-east and an associated trough moved east-north-east over the British Isles; slight rain occurred in most places on the 19th and showers in the west and north on the 20th, while gale force was reached locally in the west and north.

In the rear of this depression an anticyclone developed to the north-west of the British Isles and subsequently moved south-east across the country to a position north of the Alps; there was practically no rain in Great Britain from the 22nd–25th. Widespread fog occurred in England (except the south-west) and locally in south Scotland. From the 26th–28th a trough of low pressure associated with a depression in mid Atlantic moved slowly east and gave slight rain in Ireland and west and north Scotland. Elsewhere mainly dry conditions continued, with widespread thick fog in many eastern and Midland districts of England and locally in south Scotland. At Kingsway, London, for example, persistent fog prevailed from 2100 on the 26th to the end of the month. In places with persistent fog it was cold, particularly during the 22nd–24th and 27th–30th, but at those places which escaped the fog mild weather and long periods of bright sunshine were enjoyed.

Rainfall somewhat exceeded the average in the extreme north-west of Scotland and the Shetland Islands in the neighbourhood of the Solway Firth, in the extreme south-west of Northern Ireland and in a coastal strip of Cardigan Bay. Less than half the average rainfall occurred in a large area in east Scotland, over most of north-east England and in the south-west tip of Cornwall.

The general character of the weather is shown by the following provisional values:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	67	18	+2·3	66	−4	108	25
Scotland	62	12	+2·8	81	−2	100	21
Northern Ireland ..	62	24	+4·0	81	−6	116	29

RAINFALL OF NOVEMBER 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·76	75	*Glam.*	Cardiff, Penylan ..	2·45	60
Kent	Folkestone, Cherry Gdns.	2·49	77	*Pemb.*	St. Ann's Head ..	3·41	85
,,	Edenbridge, Falconhurst	1·95	55	*Card.*	Aberystwyth	3·90	105
Sussex	Compton, Compton Ho.	2·05	54	*Radnor*	Bir. W. W., Tyrmynydd	3·67	55
,,	Worthing, Beach Ho.Pk.	2·47	77	*Mont.*	Lake Vyrnwy	4·69	81
Hants	Ventnor, Roy. Nat. Hos.	2·37	74	*Mer.*	Blaenau Festiniog ..	10·78	101
,,	Bournemouth	1·61	47	*Carn.*	Llandudno	1·45	50
,,	Sherborne St. John ..	1·73	61	*Angl.*	Llanerchymedd ..	3·29	78
Herts.	Royston, Therfield Rec.	1·53	66	*I. Man.*	Douglas, Boro' Cem. ..	3·81	81
Bucks.	Slough, Upton	1·85	83	*Wigtown*	Port William, Monreith	4·43	103
Oxford	Oxford, Radcliffe ..	1·50	65	*Dumf.*	Dumfries, Crichton R.I.	4·15	113
N'hant.	Wellingboro', Swanspool	1·49	69	,,	Eskdalemuir Obsy. ..	5·30	91
Essex	Shoeburyness	1·67	78	*Roxb.*	Kelso, Floors	1·82	79
Suffolk	Campsea Ashe, High Ho.	1·91	86	*Peebles*	Stobo Castle	2·47	75
,,	Lowestoft Sec. School ..	1·48	63	*Berwick*	Marchmont House ..	1·87	62
,,	Bury St. Ed., Westley H.	1·47	64	*E. Loth.*	North Berwick Res. ..	2·08	92
Norfolk	Sandringham Ho. Gdns.	1·38	56	*Midl'n.*	Edinburgh, Blackf'd. H.	2·33	104
Wilts.	Bishops Cannings ..	1·38	48	*Lanark*	Hamilton W. W., T'nhill	3·20	90
Dorset	Creech Grange.. ..	2·56	62	*Ayr*	Colmonell, Knockdolian	2·75	55
,,	Beaminster, East St. ..	2·34	59	,,	Glen Afton, Ayr San ..	4·29	78
Devon	Teignmouth, Den Gdns.	1·76	55	*Bute*	Rothesay, Ardencraig	4·69	93
,,	Cullompton	2·29	67	*Argyll*	L. Sunart, Glenborrodale	5·57	74
,,	Barnstaple, N. Dev. Ath.	2·23	57	,,	Poltalloch	4·08	72
,,	Okehampton, Uplands	3·24	61	,,	Inverary Castle.. ..	7·83	93
Cornwall	Bude School House ..	2·25	63	,,	Islay, Eallabus ..	3·67	68
,,	Penzance, Morrab Gdns.	2·11	46	,,	Tiree	4·73	98
,,	St. Austell, Trevarna ..	3·55	72	*Kinross*	Loch Leven Sluice ..	2·65	74
,,	Scilly, Tresco Abbey ..	1·76	51	*Fife*	Leuchars Airfield ..	1·11	48
Glos.	Cirencester	1·75	59	*Perth*	Loch Dhu	6·69	77
Salop.	Church Stretton ..	1·87	60	,,	Crieff, Strathearn Hyd.	3·10	71
,,	Cheswardine Hall ..	2·12	82	,,	Pitlochry, Fincastle ..	2·07	56
Staffs.	Leek, Wall Grange P.S.	2·02	65	*Angus*	Montrose, Sunnyside ..	1·03	39
Worcs.	Malvern, Free Library	1·47	58	*Aberd.*	Balmoral Castle Gdns...	·82	22
Warwick	Birmingham, Edgbaston	1·54	65	,,	Dyce, Craibstone ..	1·08	33
Leics.	Thornton Reservoir ..	1·47	65	,,	Fyvie Castle	1·44	42
Lincs.	Boston, Skirbeck ..	1·42	71	*Moray*	Gordon Castle	1·79	62
,,	Skegness, Marine Gdns.	·83	38	*Nairn*	Nairn, Achareidh ..	1·74	77
Notts.	Mansfield, Carr Bank ..	·92	38	*Inv's*	Loch Ness, Foyers ..	4·93	126
Ches.	Bidston Observatory ..	..	..	,,	Glenquoich	11·10	91
Lancs.	Manchester, Whit. Park	1·84	70	,,	Fort William, Teviot ..	7·47	91
,,	Stonyhurst College ..	3·64	81	,,	Skye, Duntuilm ..	6·31	105
,,	Blackpool	2·57	74	*R. & C.*	Ullapool	4·48	87
Yorks.	Wakefield, Clarence Pk.	·88	41	,,	Applecross Gardens ..	7·00	108
,,	Hull, Pearson Park ..	·74	34	,,	Achnashellach	10·02	116
,,	Felixkirk, Mt. St. John	·68	28	,,	Stornoway Airfield ..	4·26	77
,,	York Museum	·99	47	*Suth.*	Lairg	3·86	97
,,	Scarborough	·69	28	,,	Loch More, Achfary ..	9·03	106
,,	Middlesbrough.. ..	1·34	63	*Caith.*	Wick Airfield	2·20	70
,,	Baldersdale, Hury Res.	2·70	73	*Shet.*	Lerwick Observatory ..	4·39	103
Norl'd.	Newcastle, Leazes Pk. ..	1·28	54	*Ferm.*	Crom Castle	3·69	106
,,	Bellingham, High Green	2·62	76	*Armagh*	Armagh Observatory ..	2·64	93
,,	Lilburn Tower Gdns. ..	1·21	36	*Down*	Seaforde	2·02	53
Cumb.	Geltsdale	3·26	99	*Antrim*	Aldergrove Airfield ..	2·53	78
,,	Keswick, High Hill ..	4·79	85	,,	Ballymena, Harryville..	3·00	74
,,	Ravenglass, The Grove	4·47	100	*Lon.*	Garvagh, Moneydig ..	2·53	64
Mon.	Abergavenny Larchfield	1·90	50	,,	Londonderry, Creggan	3·30	80
Glam.	Ystalyfera, Wern House	5·00	76	*Tyrone*	Omagh, Edenfel ..	3·71	98

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JULY 1948

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1016·7	+0·8	93	47	69·6	55·0	62·3	−0·7	56·3	70	7·3	1·19	−0·98	9	5·8	36
Gibraltar	1016·8	0·0	92	63	81·2	67·5	74·3	−0·5	68·5	74	3·3	0·00	—	0	10·9	76
Malta	1015·5	+0·8	89	61	81·7	66·5	74·1	−4·2	69·7	64	1·2	0·03	—	1	12·2	85
St. Helena	1019·6	−0·5	66	53	61·3	54·7	58·0	−0·3	55·0	94	9·2	6·65	+2·52	28	—	—
Lungi, Sierra Leone..	1013·9	—	87	69	81·3	72·9	77·1	—	73·8	90	8·5	27·15	—	29	—	—
Lagos, Nigeria ..	1014·2	−1·0	87	65	82·8	69·4	76·1	−1·9	74·3	85	9·1	0·67	—	8	3·0	24
Kaduna, Nigeria ..																
Chileka, Nyasaland ..	1022·3	−0·6	82	51	75·3	57·0	66·1	+1·0	58·6	70	4·6	0·14	+0·01	2	5·9	52
Lusaka, Rhodesia ..	1020·4	−0·1	81	43	74·7	50·2	62·5	+1·0	52·4	63	1·6	0·00	−0·01	0	9·0	80
Salisbury, Rhodesia..	1022·9	−0·3	76	35	69·3	45·8	57·5	+0·8	49·2	62	2·9	0·02	−0·01	1	7·4	66
Cape Town ..			76	33	62·1	46·6	54·3	−0·4				5·24	+1·62	21	—	—
Germiston, South Africa	1023·9	−1·3	70	27	64·1	41·0	52·5	+2·4	42·0	69	1·6	0·14	−0·19	1	9·3	88
Mauritius																
Calcutta, Alipore Obsy.	999·0	+0·1	95	77	89·8	79·7	84·7	+1·0	80·4	88	8·5	11·16	−1·54	27	4·4	33
Bombay	1002·9	−1·0	91	73	86·1	78·4	82·3	+0·9	78·2	87	8·6	27·16	+2·89	19	1·5	11
Madras	1003·5	−1·0	103	76	96·4	79·8	88·1	+0·5	75·8	68	8·3	3·35	−0·49	7	4·9	38
Colombo, Ceylon ..	1008·7	−0·4	87	73	85·0	77·4	81·2	0·0	76·6	87	7·5	2·70	−1·73	16	6·1	49
Singapore	1008·5	−0·4	90	72	87·4	75·9	81·7	+0·4	77·2	84	7·9	11·49	+4·70	20	—	—
Hongkong																
Sydney, N.S.W. ..	1019·7	+1·4	69	38	61·2	43·6	52·4	−0·3	46·6	62	3·0	0·77	−4·03	7	6·8	67
Melbourne	1018·9	0·0	58	30	54·7	41·0	47·9	−0·8	42·6	77	6·0	0·58	−1·28	12	3·6	37
Adelaide	1020·6	+0·4	70	37	57·6	44·6	51·1	−0·8	45·8	72	6·9	1·23	−1·41	14	3·2	32
Perth, W. Australia..	1017·8	−1·2	69	39	63·7	48·9	56·3	+1·1	52·2	71	7·0	8·65	+2·09	23	4·2	41
Coolgardie	1020·4	+0·5	71	31	60·9	41·6	51·3	+0·1	45·4	72	4·1	0·67	−0·20	7	—	—
Brisbane	1020·1	+1·7	74	37	68·7	47·7	58·2	−0·3	51·8	62	2·9	0·53	−1·67	7	8·3	78
Hobart, Tasmania ..	1014·4	+0·7	59	32	51·7	39·4	45·5	−0·2	40·9	73	6·2	1·29	−0·89	16	4·3	46
Wellington, N.Z. ..	1014·9	+1·0	60	39	52·4	43·6	48·0	+1·6	45·9	86	8·1	7·41	+1·78	24	2·4	25
Suva, Fiji	1014·5	+0·5	82	60	78·2	68·9	73·5	+0·1	69·1	77	6·7	3·17	−1·76	21	5·2	46
Apia, Samoa ..	1011·9	+0·2	87	67	85·2	71·8	78·5	+0·3	74·5	79	5·8	2·96	−0·51	12	7·4	65
Kingston, Jamaica ..	1014·4	−0·3	95	73	90·9	75·6	83·3	+1·6	76·0	69	4·3	2·23	+0·61	2	8·6	66
Grenada, W. Indies..	—	—	—	72	—	75·9	—	—	77·4	81	7·9	12·32	+2·89	29	—	—
Toronto	1013·8	−0·6	89	51	81·1	61·5	71·3	+2·2	61·6	75	5·5	1·31	−1·53	6	8·8	58
Winnipeg	1010·3	−2·0	88	45	78·2	57·9	68·1	+1·7	58·6	86	6·1	4·06	+0·96	14	8·2	52
St. John, N.B. ..	1011·7	−1·9	83	47	71·8	53·3	62·5	+2·1	57·5	85	6·5	4·09	+0·46	16	7·4	48
Victoria, B.C. ..	1016·4	−0·9	81	46	68·8	51·6	60·2	+0·1	51·6	89	5·5	1·40	+0·98	8	9·3	59

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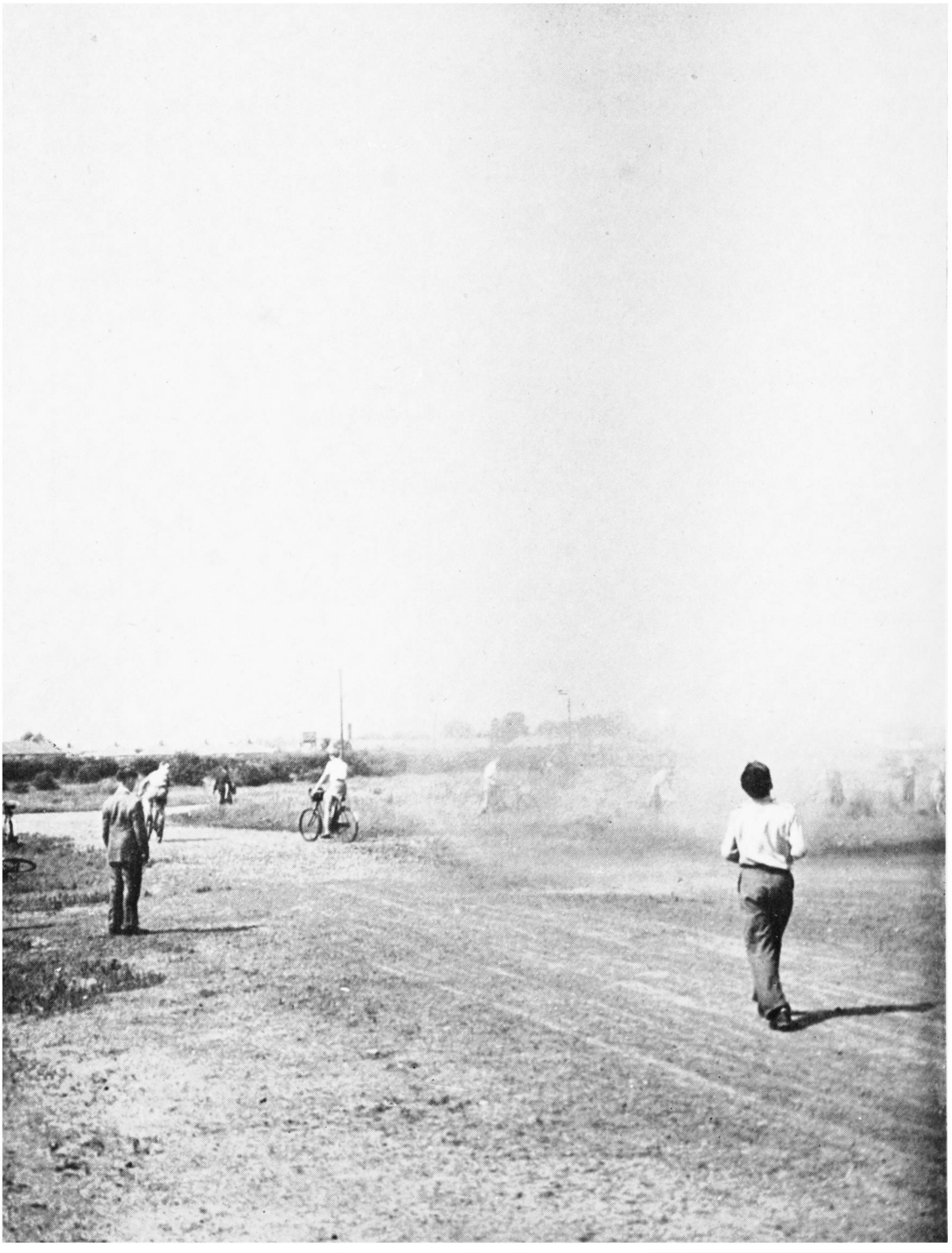
Photograph by R.A.F.

THE TOP OF A SHEET OF ALTOCUMULUS
Looking east from 20,000 ft. in 51°40′N. 5°45′E.

Photograph by R.A.F.

CUMULUS AND HAZE
Looking south from 20,000 ft. in 53°N. 4°E. November 18, 1943.



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DUST DEVIL, HOUNSLOW HEATH, JULY 8, 1945

Two dust devils occurred during the Hamley Trophy Power Contest for model aircraft in 1945. This phenomenon was strong enough to lift a large petrol model (probable weight 4–5 lb.) several feet into the air.